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JOURNAL of PALEONTOLOGY

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FORAMINIFERA OF THE GENERA *FLABELLAMMINA* AND *FRANKEINA* FROM THE CRETACEOUS OF TEXAS

C. I. ALEXANDER AND J. P. SMITH
Texas Christian University, Forth Worth, Texas

ABSTRACT

Species belonging in the genera *Flabellammina* and *Frankeina* are distributed through Cretaceous formations of Texas above the base of the Goodland limestone. They are varied in form and at some horizons are abundant. This paper describes eight species of *Flabellammina* (five new) and eight of *Frankeina* (six new).

In 1928, Dr. Joseph A. Cushman published a description of the genus *Flabellammina*,[1] naming the genotype *F. alexanderi*. The senior author of the present paper had presented the type specimens to Dr. Cushman.

In 1929, Cushman and Alexander described the genus *Frankeina*,[2] named for the distinguished paleontologist, Dr. A. Franke, of Arnstadt, Germany, with *F. goodlandensis* as the genotype. The type specimens for both of these genera were collected at an exposure of the Goodland formation at Cragin Knobs, west of Fort Worth on the "Stove Foundry" road.

One species beside the genotype has been referred to each of these two genera since the publication of the generic descriptions. Cushman and Waters described *Frankeina taylorensis*[3] from the Taylor formation, and Cushman has recently described *Flabellammina saratogaensis*[4] from the Saratoga chalk of Arkansas.

A few species, fossil and recent, described by earlier students of the foraminifera under *Haplophragmium*, *Ammobaculites* and other generic names undoubtedly belong to *Flabellammina* and *Frankeina*. Two such instances are noted in the present paper. The four species named above, however, have been the only ones assigned to these genera until the present time.

During the scholastic year 1930–31, Mr. Smith, junior author of this paper, was engaged in the preparation of a dissertation on the foraminifera of the Taylor and Navarro formations. He discovered numerous representatives of both genera in his

[1] Cushman, Joseph A., Additional Genera of the Foraminifera, *Contrib. Cushman Lab. Foram. Research*, vol. 4, 1928, p. 1, pl. 1, figs. 3, 4.

[2] Cushman, Joseph A., and Alexander, C. I., *Frankeina*, A New Genus of Arenaceous Foraminifera, *Contrib. Cushman Lab. Foram. Research*, vol. 5, 1929, p. 61, pl. 10, figs. 1, 2.

[3] Cushman, Joseph A., and Waters, J. A., Some Arenaceous Foraminifera from the Taylor Marl of Texas, *Contrib. Cushman Lab. Foram. Research*, vol. 5, 1929, p. 63, pl. 10, figs. 3*a*, *b*.

[4] Cushman, Joseph A., Foraminifera of the Saratoga Chalk, *Jour. Pal.*, vol. 5, 1931, p. 298, pl. 34, figs. 1a, b.

collections from the Taylor formation. These discoveries, and the fact that some of the species seemed to mark distinct zones within the formation, led the writers to make a careful study of collections of microfossils from all the Cretaceous formations of Texas.

No representatives of either genus were found in formations below the Goodland. In formations ranging upward from the base of the Goodland through the entire upper part of the Lower Cretaceous or Comanchean series, and in the Austin and Taylor formations and their stratigraphic equivalents of the Upper Cretaceous, representatives of both genera were found in variety, and at some localities and horizons, in abundance. No representatives of either genus were found in the Navarro formation, although occasional individuals of one species of *Flabellammina* have been discovered in the equivalent Escondido formation of south Texas.

Some species of arenaceous foraminifera exhibit great selectivity in choosing the materials for the construction of the test, always selecting fragments of a particular size or shape, regardless of whether the desired clasts are abundant or rare in the environment in question. Most species, however, do not exhibit marked selectivity, incorporating fragments of various shapes and sizes in the shell wall. The test of most species, therefore, may vary considerably in appearance according to the type of fragmental material which is common on the sea-floor where the individual lives. For this reason, the writers have carefully avoided basing species distinctions on the nature of the fragments composing the test. The features of greatest significance in distinguishing the species of *Flabellammina* and *Frankeina* are size, shape and proportions of the test, degree of depression of sutures, and similar structural characters.

The writers wish to express their gratitude to Dr. Joseph A. Cushman for reading the manuscript and offering helpful suggestions in the delineation of the species, and to Miss Margaret S. Moore, of Sharon, Massachusetts, for her fine coöperation in the preparation of the figures for the plates.

DESCRIPTION OF SPECIES

Family LITUOLIDAE

Genus FLABELLAMMINA Cushman

Test compressed, early chambers close-coiled, planispiral, later chambers uniserial, wide, and more or less strongly recurved, extending back along the sides of the test in an inverted V-shape, or in a broad arch. Microspheric form usually broader than megalospheric form. Wall of test arenaceous. Aperture terminal, simple, elliptical to slit-like.

FLABELLAMMINA ALEXANDERI Cushman

Plate 45, figures 1–5, 15

Flabellammina alexanderi CUSHMAN, *1928*, Contrib. Cushman Lab. Foram. Research, vol. 4, p. 1, pl. 1, figs. 3, 4.

Test compressed, leaf-like. Sur-

faces of test flat, periphery narrowly rounded. Outline of test variable, some megalospheric individuals being narrow and lanceolate in form while microspheric specimens are occasionally so broad as to be almost circular in outline. In most specimens the early coil is entirely enclosed by the contour of the later chambers, forming an ovate or elliptical test, but in some it is not so enclosed, and thus forms a distinct hook at the initial end of the test. Sutures indistinct, last one or two very slightly depressed in some individuals. Wall arenaceous, composed of fine material, with some coarse, calcareous fragments. These larger fragments are usually elongated, and oriented parallel to the sutures. Surface smoothly finished. Aperture terminal, elongate, elliptical.

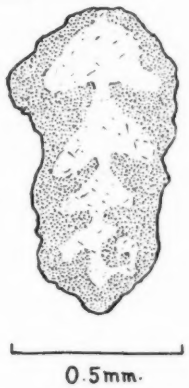


FIG. 1. Sketch of longitudinal section, through plane of coiling of a specimen of *Flabellammina rugosa* Alexander and Smith, n. sp.

Measurements of the two specimens figured in figures 1 and 2, from the type locality of the species, are as follows; microspheric form, length, 0.75 mm., width, 0.48 mm.; megalospheric form, length, 0.9 mm., width, 0.35 mm.

Representatives of this species have been found by the writers from all the Lower Cretaceous formations from the base of the Goodland upward through the Georgetown and Del Rio formations of south Texas, and through the equivalent formations of north Texas with the exception of the Grayson. The apparent absence of the species from the Grayson clays is remarkable since it is very abundant in the Del Rio. Helen Jeanne Plummer records the species from the Walnut formation at Mt. Barker, near Austin.[5] Through her courtesy the writers have specimens from this locality, and find them to be typical representatives of the species.

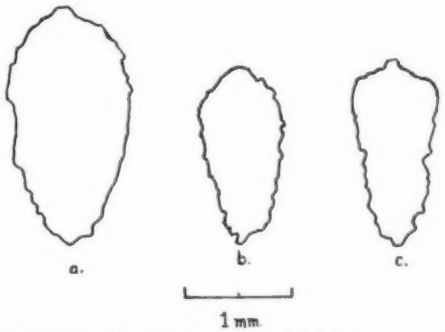


FIG. 2. Outline of drawings of (*a*) holotype of *Flabellammina washitensis* Alexander and Smith, n. sp.; (*b*) paratype of *F. rugosa* A. and S., n. sp., shown in pl. 45, fig. 8; and (*c*) holotype of *F. rugosa*, drawn to same scale.

The plesiotypes shown in Plate 45, figures 1 and 2, are from the type locality for the species, an exposure of

[5] Plummer, Helen Jeanne, Some Cretaceous Foraminifera in Texas, *Texas, Univ.* Bull. 3101, 1931, p. 127.

upper Goodland at Cragin Knobs, three miles west of the Texas and Pacific railroad shops in Fort Worth, on the "Stove Foundry" road, and are in the Alexander Collections, No. F-2301.1; plesiotypes, figures 3 and 4, from Del Rio clays, exposed in two low, rounded hills near the southern edge of the city of Del Rio, in Alexander Collections No. F-2301.2; plesiotypes, figures 5 and 15, from an exposure of the Denton formation, in the east bank of Denton Creek, 1.4 miles east of Justin, Denton County, Texas, in Alexander Collections No. F-2301.3.

FLABELLAMMINA RUGOSA
Alexander and Smith, n. sp.
Plate 45, figures 6–9; text figure 1

Test compressed, elongate, narnow. Periphery rounded, rough and irregular. Chambers of uniserial portion few, high, and only slightly recurved. Sutures indistinct. Wall very coarsely arenaceous, consisting chiefly of large, calcareous fragments, *Inoceramus* prisms being common and conspicuous, calcareous-shelled foraminifera and similar materials in a groundmass of finer material. Surface of test roughly finished.

Measurements of holotype, figure 7; length, 1.7 mm., width, 0.8 mm.

The sutures of this species are so indistinct, the form so irregular, and the surface so rough that it is almost impossible to observe the arrangement of the chambers, except in section. Text figure 1 illustrates a section prepared for this purpose. Sections of several specimens, all from the type locality, were prepared, and all showed exactly this same arrangement. The specimen figured here was selected for illustration because it was the best section of the several which were made. The interior of the chambers, in this individual, were filled with crystalline calcite, which causes them to contrast strongly with the granular material composing the wall of the test.

This species has been found in samples from the Duck Creek formation of the Lower Cretaceous, and from the upper Austin and the Gober tongue of the Austin formation of the Upper Cretaceous. It appears to be widely distributed in both of its stratigraphic occurrences. These widely separated stratigraphic occurrences indicate that *F. rugosa* is probably a long-lived species. Although the writers' samples have failed to yield any specimens referable to this species from the intervening formations, future collections from the proper localities will possibly discover them.

The holotype, Alexander Collections No. F-2302.1, collected at an exposure of lower Duck Creek limestone and marl in the south bank of a small creek, about 15 feet north of the road leading eastward from Fink, Grayson County, Texas, at a point 1.0 mile east of town; the paratype illustrated in Plate 45, figure 6, Alexander Collections No. F-2302.2, from the same locality; paratypes, figures 8 and 9, Alexander Collections No. F-2401.1, from upper Austin chalk from the bank of a small stream just west of a concrete culvert, 3.4 miles

northeast of White Rock dam, on the Dallas-Garland road.

FLABELLAMMINA LONGIUSCULA
Alexander and Smith, n. sp.
Plate 45, figures 13, 16;
Plate 46, figure 1

Test thick, moderately compressed, elongate, of nearly uniform width throughout entire length, chambers increasing slightly in width as added. Margins of test nearly straight, periphery rounded. Chambers high, broadly arched, slightly recurved. Sutures indistinct, very slightly depressed. Wall coarsely arenaceous. Length of holotype, Plate 46, figure 1, 3.1 mm., width, 1.7 mm.

Unfortunately, at the time the illustrations were prepared, no complete individuals of this species had been found. The long, slender tests had been broken by the rather crude methods of washing employed at the time the concentrates from which these specimens came were prepared. Careful washing of clays from the same localities has recently yielded several perfect specimens. The holotype, if complete, would probably measure as much as 4 mm. in length.

The influence of environment in determining the appearance of the test of many arenaceous foraminifera is well illustrated by this species. The paratypes, Plate 45, figures 13 and 16, were collected at an exposure of upper Denton clays, in the north bank of a small tributary of Sycamore Creek, about 0.25 mile east of Katy Lake dam, Fort Worth. The clays from this exposure yield innumerable shells of adults and juveniles of the fossil oyster *Gryphea washitaensis* Hill, and tests of *Flabellammina longiuscula* from the same clays contain many large, flake-like fragments of these shells, giving the test a distinctly scaly appearance.

F. longiuscula ranges from upper Duck Creek through the Fort Worth and Denton formations. Representatives of the species have not been found in formations above the Denton.

Holotype, from upper Duck Creek, exposed in a road cut at the north end of Rogers Avenue, 0.38 mile north of the campus of Texas Christian University, in Alexander Collections No. F-2303.1; paratypes, Alexander Collections No. F-2303.2.

FLABELLAMMINA WASHITENSIS
Alexander and Smith, n. sp.
Plate 45, figures 10, 11

Test compressed, thin, surfaces of test broad and flat. Chambers of uniserial portion rather high, only slightly recurved. Sutures indistinct. Wall coarsely arenaceous, composed of fragments of varying size and shape, firmly cemented and fairly smoothly finished. Aperture terminal, slit-like, at the end of a short, but distinct neck.

Length of holotype, figure 10, 2.15 mm., width, 1.1 mm.

The figures of this species and of *F. rugosa* make the two appear very similar. The difference in magnification employed in drawing the representatives of the two species fails to show a very constant and characteristic difference in size which makes the two species easy to distinguish. In text figure 2, specimens are drawn in outline, to the same scale; *a* is the

holotype of *F. washitensis*, *b* and *c* are specimens of *F. rugosa*, *b* is the paratype illustrated in Plate 45, figure 8, and *c* the holotype. These outline drawings illustrate not only the distinct difference in size, but also the fact that tests of *F. rugosa* are characteristically widest near the apertural end, while those of *F. washitensis* are widest near the middle of the total length. The present species, also, does not employ fragments as large as those incorporated in tests of *F. rugosa*, and is more smoothly and compactly finished.

F. washitensis has been found in concentrates from the Fort Worth, Denton and Weno formations. Specimens are most numerous in samples from the Fort Worth, but are never very common.

Holotype, Alexander Collections No. F-2304.1, from an exposure of Fort Worth limestone in a road cut three miles north of Ponder on the Fort Worth-Sanger highway; paratype, Alexander Collections No. F-2304.2, from upper Fort Worth limestone and marl at an exposure of upper Fort Worth and lower Denton on the east bank of Denton Creek, 1.4 miles east of Justin.

FLABELLAMMINA CLAVA
Alexander and Smith, n. sp.
Plate 45, figures 12, 14

Test elongate, early portion somewhat compressed, terminal portion thickened, in some individuals terminal chambers distinctly inflated, giving the test a club-like appearance. Sutures indistinct, in many specimens not visible externally. Wall coarsely arenaceous, composed largely of elongated fragments of *Inoceramus* prisms and other large, angular clasts embedded in a groundmass of finer material. Surface roughly finished.

Length of holotype, figure 14, 2.0 mm., width, 0.85 mm.

F. clava appears to be an excellent horizon marker, being restricted to the upper part of the Austin chalk in north Texas. The distinctive shape and large size make this species an easy one to recognize.

EXPLANATION OF PLATE 45

FIGS. 1–5—*Flabellammina alexanderi* Cushman, all figures ×30. 1, 2, Microspheric and megalospheric forms, from Goodland formation, type locality; 3, 4, microspheric and megalospheric forms from Del Rio formation; 5, megalospheric form from Denton formation.

6–9—*Flabellammina rugosa* Alexander and Smith, n. sp. 6, Paratype, from Duck Creek formation, ×22; 7, holotype, from Duck Creek formation, ×22; 8, 9, paratypes, from Austin formation, ×25.

10, 11—*Flabellammina washitensis* Alexander and Smith, n. sp., ×18. 10, Holotype, 11, paratype, from Fort Worth formation.

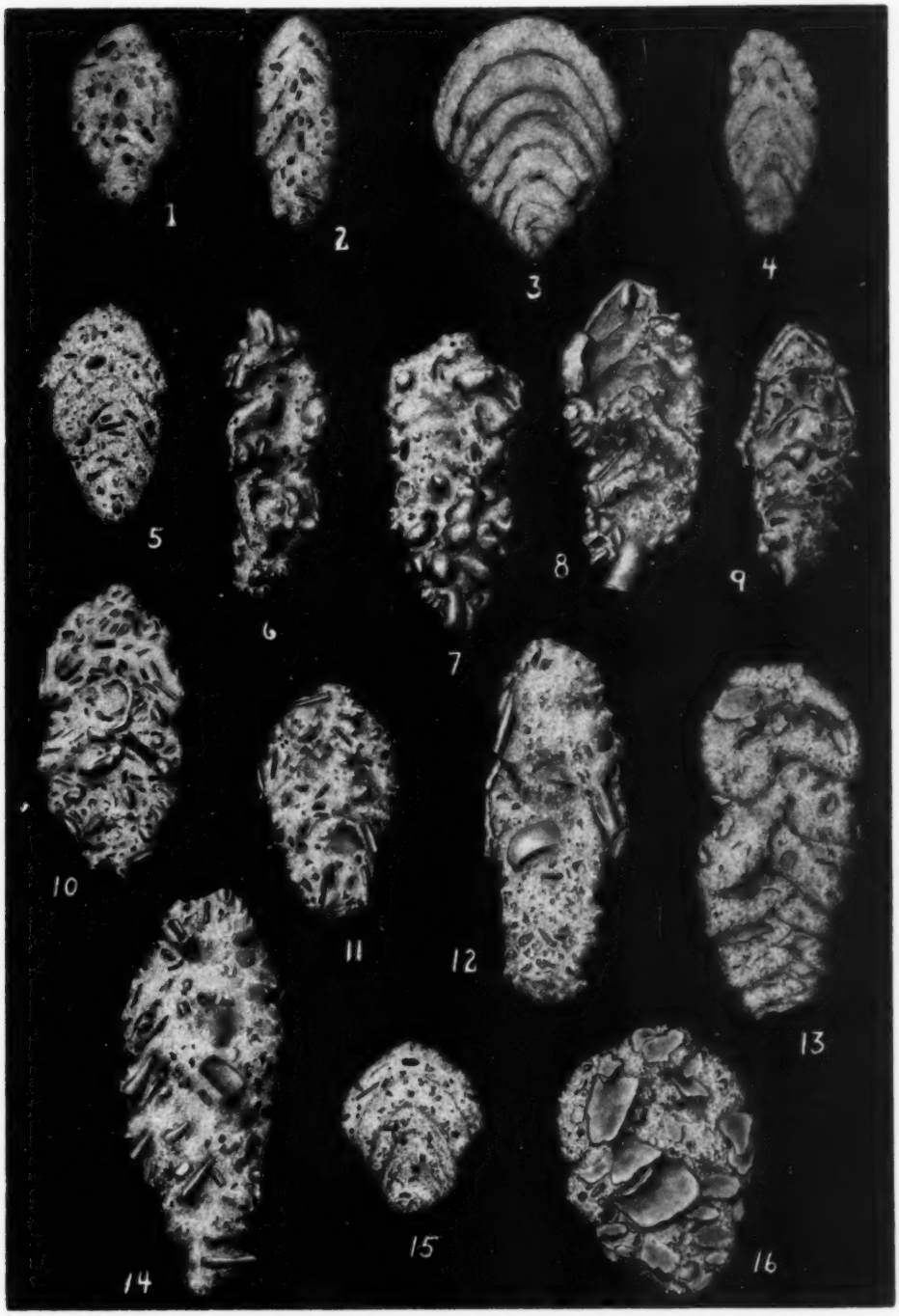
12—*Flabellammina clava* Alexander and Smith, n. sp., ×25. Paratype, from Austin formation.

13—*Flabellammina longiuscula* Alexander and Smith, n. sp., ×16. Paratype, from Denton formation.

14—*Flabellammina clava* Alexander and Smith, n. sp., ×25. Holotype, from Austin formation.

15—*Flabellammina alexanderi* Cushman, ×30. Microspheric form, from Denton formation.

16—*Flabellammina longiuscula* Alexander and Smith, n. sp., ×16. Paratype, from Denton formation.



Alexander and Smith, Cretaceous Foraminifera

Holotype, and paratype, Alexander Collections Nos. F-2402.1 and F-2402.2 respectively, from a thick clay seam in the upper Austin chalk, exposed in a road cut at the southern edge of the city of McKinney, on the Dallas-Sherman highway.

FLABELLAMMINA SARATOGAENSIS Cushman

Plate 46, figure 4

Flabellammina saratogaensis CUSHMAN, *1931*, Jour. Pal., vol. 5, p. 298, pl. 34, figs. 1a, b.

Test much compressed, periphery rounded. Test of nearly uniform width throughout entire length; diameter of early, close-coiled portion nearly equal to width of first chambers of uniserial series, later chambers of uniserial series increasing in width very gradually as added. Chambers of uniserial portion few (3–5) in number, rather high, and slightly recurved. Sutures fairly distinct, slightly depressed. Wall coarsely arenaceous, composed of fragments of irregular shape and size, firmly cemented and with a fairly smooth surface. Aperture elliptical, at the end of a slight terminal elevation.

Length of plesiotype, 1.5 mm., width, 0.8 mm.

F. saratogaensis Cushman was first described from the Saratoga chalk of Arkansas, commonly regarded as the equivalent of the lower Navarro of Texas. The authors' specimens, collected from middle Taylor clays, near Austin, do not differ in any fundamental character from the Saratoga forms. The writers have compared their specimens with numerous individuals from the Arkansas type locality, and have submitted their plesiotype to Dr. Cushman for comparison with the holotype. Dr. Cushman agrees that the two forms are specifically identical.

Plesiotype, Alexander Collections No. F-2403.1, from chalky Taylor clays about 150 feet above the top of the Austin formation, from an exposure in a gully north of the Austin-Manor highway, near the east end of a bridge over Walnut Creek, six miles northeast of Austin.

FLABELLAMMINA COMPRESSA (Beissel)

Plate 46, figures 2, 3, 5–9

Haplophragmium compressum BEISSEL, *1891*, Abhandl. König. Preuss. geol. Landes., Neue Folge, Heft 3, p. 16, pl. 4, figs. 11–23.
Ammobaculites compressum FRANKE, *1928*, Abhandl. Preuss. geol. Landes., Neue Folge, Heft 111, p. 166, pl. 15, fig. 10.

Test strongly compressed, with broad, flat surfaces and bluntly rounded periphery. Outline variable; most individuals increase very gradually in width toward the apertural end, and have nearly straight, approximately parallel margins; others increase more rapidly in width and have broadly ovate outlines. Sutures fairly distinct, slightly depressed. Wall of test coarsely arenaceous, composed of angular mineral fragments; clear quartz grains predominate, but dark-colored minerals are common and conspicuous.

Measurements of the plesiotype pictured in Plate 46, figure 5, which was the largest specimen found, length 2.4 mm., width, 1.4 mm.

Through the generosity of Dr. Franke, the authors were able to secure representatives of this species from the Upper Cretaceous of Ger-

many. These specimens from the type area do not exhibit the dark-colored mineral fragments which characterize the tests of the Texas forms, but this difference is obviously one of environment, and the individuals of the two groups are exactly similar in every other character.

Members of this species have been found in every sample from the Pecan Gap member of the Taylor formation in the writers' collections. Specimens have also been collected from the Annona chalk of northeastern Texas, the upper part of which is correlated with the Pecan Gap chalk, and from one locality stratigraphically higher than the Pecan Gap, near Austin. Tests of individuals from the Pecan Gap are characteristically more coarsely arenaceous than those from the Annona chalk, or from the south Texas locality.

Plesiotypes, Plate 46, figures 2, 3, 7 and 8, from Pecan Gap calcareous clays, exposed in a shallow roadside ditch north of the Forney-Mesquite road at a point 0.7 mile west of Forney, Alexander Collections No. F-2404.1; plesiotypes, figures 5, 6 and 9, from upper Taylor clays exposed in the bank of a small stream 200 yards south of the bridge where Pierce's Lane crosses the stream, 1.5 miles south of Del Valle, in Alexander Collections No. F-2404.2.

FLABELLAMMINA MAGNA
Alexander and Smith, n. sp.
Plate 46, figures 10, 11

Test large, long, rather thick and only moderately compressed, surfaces flat or slightly concave, periphery rounded. Test of microspheric form increases rather rapidly in width toward apertural end, giving test a broadly spatulate form; megalospheric form more slender, last one or two chambers not as wide as preceding ones, so that test tapers toward apertural end. Chambers of uniserial portion from 8 to 10 in number, moderately recurved. Sutures depressed, last two or three rather strongly depressed, especially near the median line of the test. Wall coarsely arenaceous, composed of large, angular mineral fragments.

Measurements, microspheric form, length 3.65 mm., width 2.15 mm., megalospheric form, length 4.2 mm., width, 1.9 mm.

This large, conspicuous form has been found in samples from the Pecan Gap chalk, and from one exposure of Escondido clays in a road cut on the San Antonio-Castroville

EXPLANATION OF PLATE 46

FIGS. 1—*Flabellammina longiuscula* Alexander and Smith, n. sp., ×16. Holotype, from Duck Creek formation.
2, 3—*Flabellammina compressa* (Beissel), ×20. Plesiotypes, from Pecan Gap chalk member of Taylor formation.
4—*Flabellammina saratogaensis* Cushman, ×25. Plesiotype, from Taylor formation.
5–9—*Flabellammina compressa* (Beissel). 5, 6, Plesiotypes from upper Taylor, ×16; 7, 8, plesiotypes from Pecan Gap chalk member of Taylor, ×20; 9, plesiotype from upper Taylor, ×16.
10, 11—*Flabellammina magna* Alexander and Smith, n. sp., ×16; cotypes. 10, Microspheric form; 11, megalospheric form, from Taylor formation.

Alexander and Smith, Cretaceous Foraminifera

highway, five miles east of Castroville.

Cotypes, Alexander Collections No. F-2405.1, collected from Pecan Gap calcareous clays exposed in a roadside ditch 0.7 mile west of Forney on the Forney-Mesquite road.

Genus FRANKEINA Cushman and Alexander

Test in early stages close-coiled, planispiral, compressed; later uncoiling and becoming uniserial, triangular in section, the sides more or less concave. Sutures bent toward apertural end at middle of each concave face and recurved toward initial end at the angles. Wall of test arenaceous. Aperture terminal, simple, elliptical to slit-like.

FRANKEINA GOODLANDENSIS
Cushman and Alexander
Plate 47, figure 8

Frankeina goodlandensis CUSHMAN AND ALEXANDER, *1929*, Contrib. Cushman Lab. Foram. Research, vol. 5, p. 62, pl. 10, figs. 1, 2.

Test small, elongate, somewhat tapering. Chambers of uniserial portion from 4 to 5 in number. Sides of uniserial portion concave, angles rounded. Sutures slightly depressed, bent rather strongly toward apertural end at middle of each concave face. Wall coarsely arenaceous, with fragments of *Inoceramus* prisms and other large fragments embedded in a groundmass of finer material. Surface smoothly finished.

Length of plesiotype, 1.1 mm.; width, 0.55 mm.

F. goodlandensis occurs in abundance in the upper half of the Goodland formation. Occasional specimens have been observed in samples from the Washita formations of north Texas and from the Del Rio formation in south Texas. The writers have never collected more than three or four specimens from localities other than exposures of upper Goodland, however, and individuals in any numbers may be regarded as diagnostic of this level.

Plesiotype, from the type locality, an exposure of upper Goodland at Cragin Knobs, three miles west of the Texas and Pacific railroad shops in Forth Worth, on the "Stove Foundry" road, in Alexander Collections No. F-2305.1.

FRANKEINA ACUTOCARINATA
Alexander and Smith, n. sp.
Plate 47, figures 1, 6

Test long, planispiral portion thin, much compressed, uniserial portion with sides strongly concave and with angles sharp near initial end, but becoming more bluntly rounded near apertural end. Uniserial portion of test enlarges rapidly; in microspheric form test widest at about middle, tapering toward apertural end, in megalospheric form widest near apertural end. Sutures slightly depressed, chambers rather strongly recurved at angles. Wall coarsely arenaceous, composed of large, angular fragments of molluscan and foraminiferal shells, *Inoceramus* prisms and similiar clasts embedded in a groundmass of finer material, and rather smoothly finished. Aperture long, slit-like, at the end of a low, ridge-like terminal elevation.

Length of holotype, figure 1, 3.3 mm., width, 1.4 mm.

This species is restricted to the lower one-half of the Washita division of the Comanchean series, having been found in samples from formations ranging from Duck Creek to Weno in north Texas and from the lower Georgetown in south Texas. *Frankeina acutocarinata*, like *Flabellammina longiuscula*, illustrates in striking manner the effect of environment on composition of the test, specimens from the Denton formation including so many flaky fragments of shells of *Gryphea washitaensis* Hill, that the test has a distinctly scaly appearance.

Holotype, Alexander Collections No. F-2306.1, collected from lower Duck Creek, exposed in a low cliff on the south bank of a small creek, one mile east of Fink, Grayson County, Texas; paratype from upper Fort Worth limestone, in a shallow road cut about 100 yards east of the intersection of the Fort Worth-Sanger highway with an east-west road, and just east of a railroad-underpass, 4.9 miles north of Haslet, in Alexander Collections No. F-2306.2.

FRANKEINA INSOLITA
Alexander and Smith, n. sp.
Plate 47, figures 2, 3

Test long, planispiral portion compressed, uniserial portion at first triangular in section, enlarging rapidly, then becoming abruptly somewhat smaller and either square in section or in some individuals somewhat compressed and flattened. Sides of test in triangular portion concave, angles bluntly rounded. Sutures obscure. Wall very coarsely arenaceous, composed of fragments varying greatly in size and shape, with *Inoceramus* prisms and the tests of calcareous-shelled foraminifera common and conspicuous. Surface rather roughly finished.

Length of holotype, figure 3, 2.7 mm., width 0.9 mm.

F. insolita has been found in samples from the Duck Creek formation only, and is thus an excellent marker of basal Washita.

Holotype and paratype from an exposure of lower Duck Creek, exposed in the south bank of a creek one mile east of Fink. Holotype, Alexander Collections No. F-2307.1, paratype No. F-2307.2.

FRANKEINA INCERTA
Alexander and Smith, n. sp.
Plate 47, figure 4

Planispiral portion of test strongly compressed, usually followed by one or two compressed *Flabellammina*-like chambers; later portion of test triangular in section, enlarging rapidly toward apertural end. Sides of test only slightly concave, angles rounded. Sutures obscure. Wall coarsely arenaceous, composed largely of elongated fragments of *Inoceramus* prisms in a groundmass of finer material. Surface smoothly finished. Aperture slit-like, at the end of a slight neck.

Length of holotype 1.7 mm., width, 0.95 mm.

In many individuals of *F. incerta*, the test never becomes truly triangular, a low, median-longitudinal ridge

being developed in the terminal one half of the compressed, *Flabellammina*-like test. It seemed possible, therefore, that the species was a *Flabellammina* which acquired a *Frankeina*-like appearance through the addition of a ridge of agglutinated arenaceous material to the median-longitudinal line of the test. Sections made through this ridge, however, demonstrate that even in those forms in which the ridge is least pronounced, it is the external expression of recurved angles of the terminal chambers, and the species is therefore a typical *Frankeina*.

This species has been found to occur in the Fort Worth, and rarely, in the Denton formation.

Holotype from upper Fort Worth, at an exposure of upper Forth Worth and lower Denton, in the east bank of Denton Creek 1.4 miles east of Justin, No. F-2308.1 in Alexander Collections.

FRANKEINA WENOENSIS
Alexander and Smith, n. sp.
Plate 47, figure 5

Coiled portion of test small and inconspicuous; uniserial portion of nearly uniform width throughout entire length of test, with margins nearly straight and parallel. Sides of test very slightly concave, angles broadly and bluntly rounded. Sutures slightly depressed. Wall of test arenaceous, consisting of firmly and smoothly cemented fragments of moderate and fairly uniform size. Aperture at end of a slight terminal protuberance.

Length of holotype, 1.4 mm.; width, 0.9 mm.

This species is restricted to the Weno formation, but the fact that it is a rather rare form detracts from its value as an horizon marker. The writers' collections have failed to disclose a locality where individuals occur in abundance.

Holotype, Alexander Collections No. F-2309.1, collected from an exposure of upper Weno in a roadside ditch on the Fort Worth-Mansfield road, 0.25 mile south of the bridge where the highway crosses Sycamore Creek.

FRANKEINA CUSHMANI
Alexander and Smith, n. sp.
Plate 47, figures 10, 11

Haplophragmium murchisoni BEISSEL (not Reuss) *1891*, Abhandl. König. Preuss. geol. Landes., Neue Folge, Heft 3, p. 15, pl. 4, figs. 1–10.
Ammobaculites murchisoni FRANKE, *1928*, Abhandl. Preuss. geol. Landes., Neue Folge, Heft 111, p. 165, pl. 15, fig. 5.

Planispirally coiled portion of test well-developed and prominent. Uniserial portion with few (3 to 6) chambers; sides concave, angles rounded. Sutures depressed, slightly near angles, more strongly near middle of concave faces. Wall coarsely arenaceous, composed of large, angular mineral grains, with occasional fragments of foraminiferan and molluscan shells. Surface rather roughly finished.

Length of holotype, figure 11, 1.5 mm.; width, 0.85 mm.

F. cushmani is an excellent horizon marker, appearing in greater or lesser abundance in all samples collected by the writers from the Pecan Gap mem-

ber of the Taylor formation. Members of the species have been found in only one sample from strata of other than Pecan Gap age. This sample is from upper Taylor clays 1.5 miles south of Del Valle. Plesiotypes of *Flabellammina compressa* Beissel were also collected at this locality. Specimens of *Frankeina cushmani*, as well as those of *Flabellammina compressa* from this locality have tests composed of somewhat smaller mineral fragments than members of the same species from Pecan Gap localities.

This species was figured and described by Beissel as *Haplophragmium murchisoni* Reuss, as Beissel identified his specimens with forms described by Reuss under the name *Triplasia murchisoni*.[6] However, the forms described and figured by Beissel are not generically identical with *Triplasia murchisoni* Reuss, and since the rules of nomenclature require that a new name be proposed for these forms, the writers take pleasure in naming the species for Dr. Joseph A. Cushman, of Sharon, Massachusetts.

Holotype, No. F-2406.1 in Alexander Collections, and paratype, No. F-2406.2, from an abandoned quarry or pit, one mile east of Farmersville, on the Farmersville-Greenville road.

FRANKEINA TAYLORENSIS
Cushman and Waters
Plate 47, figures 7, 9

Frankeina taylorensis CUSHMAN AND WATERS, *1929*, Contrib. Cushman Lab. Foram. Research, vol. 5, p. 63, pl. 10, figs. 3a, b.

Test large, long; planispiral portion reduced, inconspicuous; uniserial portion with strongly concave sides and rounded angles. Chambers of uniserial portion numerous, distinct, last two or three slightly inflated. Sutures near initial end slightly depressed, toward apertural end more

[6] Reuss, A. E., Charakteristik der Kreideschichten in den Ostalpen, *Denks. Kais. Akad. Wissen.* Wien, Bd. 7, 1854, p. 65, pl. 25, figs. 1, 2.

EXPLANATION OF PLATE 47

FIGS. 1—*Frankeina acutocarinata* Alexander and Smith, n. sp., ×16. Holotype, from Duck Creek formation.

2, 3—*Frankeina insolita* Alexander and Smith, n. sp., ×16. 2, Paratype, *a*, side view, *b*, end view; 3, holotype; both paratype and holotype from Duck Creek formation.

4—*Frankeina incerta* Alexander and Smith, n. sp., ×16. Holotype, from Fort Worth, formation.

5—*Frankeina wenoensis* Alexander and Smith, n. sp., ×16, Holotype, from Weno formation.

6—*Frankeina acutocarinata* Alexander and Smith, n. sp., ×16. Paratype, from Fort Worth formation.

7—*Frankeina taylorensis* Cushman and Waters, ×16. Plesiotype, from Taylor formation; *a*, side view, *b*, end view.

8—*Frankeina goodlandensis* Cushman and Alexander, ×20. Plesiotype, from Goodland formation, type locality.

9—*Frankeina taylorensis* Cushman and Waters, ×16. Plesiotype, from Taylor formation.

10, 11—*Frankeina cushmani* Alexander and Smith, n. sp., ×20. 10, Paratype; 11, holotype, from Pecan Gap chalk member of Taylor formation.

12, 13—*Frankeina rugosissima* Alexander and Smith, n. sp., ×16. 12. Paratype; 13, holotype, from Taylor formation.

Alexander and Smith, Cretaceous Foraminifera

strongly depressed, especially at middle of concave faces. Wall coarsely arenaceous, somewhat roughly finished. Aperture a long, terminal slit.

Length of plesiotype pictured in figure 7, 3.3 mm., width, 1.45 mm.

F. taylorensis was first described from the Taylor formation, from a well drilled by the Sun Oil Company in Caldwell County, Texas. The species appears in surface samples from the upper portion of the Taylor formation only, and seems to be restricted in geographic distribution to south Texas.

Plesiotypes, Alexander Collections No. F-2407.1, from upper Taylor clays exposed in the bank of a small creek, 200 yards south of a bridge where Pierce's Lane crosses the stream 1.5 miles south of Del Valle, near Austin, Texas.

FRANKEINA RUGOSISSIMA
Alexander and Smith, n. sp.
Plate 47, figures 12, 13

Test large, elongated, planispiral portion well developed, compressed, uniserial portion enlarging rapidly near initial end, then remaining of nearly uniform width throughout greater part of length. In some individuals last two or three chambers tend to become somewhat smaller than preceding ones, somewhat flattened or depressed, and slightly inflated. Sides of triangular portion of test concave, angles bluntly rounded. Sutures slightly depressed, obscure near initial end, becoming more strongly depressed and distinct toward apertural end. Wall very coarsely arenaceous, composed of large mineral fragments of irregular size and shape, with numerous shells of calcareous foraminifera, fragments of shells of mollusca, ostracoda, and similar clasts. Wall firmly cemented, roughly finished. Aperture slit-like, at the end of a low, terminal protuberance.

Length of holotype, figure 13, 3.75 mm., width, 1.85 mm.

This species has been found only in the lower-middle Taylor clays, and like *F. taylorensis* seems to be restricted in geographic distribution, to the southern portion of the state.

Holotype, No. F-2408.1 in Alexander Collections, and paratype, No. F-2408.2, from chalky Taylor clays in a gully north of the Austin-Manor highway, near the east end of a long bridge over Walnut Creek, six miles northeast of Austin.

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NEW SPECIES FROM THE COLORADO GROUP, CRETACEOUS, IN SOUTH CENTRAL WYOMING

RAYMOND SIDWELL
Lubbock, Texas

ABSTRACT

This paper describes five new species of pelecypods, four of gastropods, and one each of scaphopod and cephalopod from the lower part of the Upper Cretaceous rocks of Wyoming.

INTRODUCTION

The Colorado group of south central Wyoming includes about 2500 feet of sediments, chiefly shales separated by relatively thin oil-bearing sands. These rocks, for the most part, are exposed on the limbs of the major anticlines by the removal of the overlying sediments.

The outcrops of the rocks of the Colorado group, within the scope of this report, may be separated into three distinct divisions. The southwest division, located in the extreme southwestern portion of the area, includes a series of exposures with a total length of about 25 miles in the vicinity of Rawlins, Wyoming. The central division includes outcrops which extend with a general northwest strike along the west side of the Laramie Mountains from the south end of Centennial valley for 75 miles. At Como Ridge the strike assumes a more westerly direction along the southeast flank of Flat Top anticline, Freezeout Hills, and Ferris Mountain. The northeast division includes the outcrops in the vicinity of Alcova and Casper Mountain.

Rocks of the Colorado group of south central Wyoming have been subdivided into the following formations, in order from oldest to youngest: Thermopolis, Mowry, Frontier, Carlile, and Niobrara.

The material described in this paper was collected from outcrops in the Laramie Basin; about two miles northeast of the town of Medicine Bow; four miles northeast of Rawlins; in the vicinity of the Platte River where it cuts through the west end of Casper Mountain; on the west side of Ferris Mountain, and near the town of Alcova.

The identification and description of the fossils were completed at the University of Iowa under the guidance of the late Dr. A. O. Thomas. The writer especially wishes to acknowledge the valuable assistance of Dr. Thomas. Thanks are also due Dr. J. B. Reeside, Jr., of the United States Geological Survey, who checked the identification of the fossils and submitted valuable information.

DESCRIPTION OF SPECIES

Class PELECYPODA

Genus PINNA Linné

PINNA REESIDEI Sidwell, n. sp.

Plate 48, figures 1, 2

Shell elongate, triangular, rhombic in cross-section and compressed laterally, with a tendency to become lenticular posteriorly. Dorsal margin straight or broadly concave, ventral margin with slight convexity. Each valve is divided longitudinally by a strong nearly median line located along the area of greatest convexity. This line is more conspicuous on the anterior portion of the valves and is apparent only on exfoliated specimens since it appears to represent an internal longitudinal ridge best developed inside the older and more angular portion of the shell. From the position of the median line the surface curves or slopes both dorsally and ventrally to meet that of the opposite valve in a sharp angle. These angles are in sharp contrast to the more obtuse angles at the median line. The median angularity is better marked on the anterior than on the posterior part of shell.

Shell above the median line is marked by eight or ten ridges separated by shallow furrows that are narrow anteriorly, becoming wider posteriorly. Below the median line, the marking is difficult to determine owing to the poor preservation, but there is a suggestion of ridges similar to the ones described above, limited, however, to three or four in number and located immediately below the median surface. There are faint growth-lines that curve upward on the posterior end of the shell but they are cut off anteriorly by the convex surface of the ventral margin. Crossing the ridges at nearly right angles on the upper portion of the shell are low, poorly defined costae that may be an extension of the curved growth-lines. Along the median surface the shell is thicker and consists of well developed prismatic structure. Beneath this thicker portion of the shell are uneven irregular lines and furrows that curve upward from the median line toward the posterior end of the shell.

DIMENSIONS

Specimen	*Length of fragment in mms.*	*Length of complete specimen in mms.*
A	140	205 ±
B	90	210 ±
C	70	150 ±

Specimen	*Long diameter of rhomb in mms.*		*Short diameter of rhomb in mms.*	
	Posterior	*Anterior*	*Posterior*	*Anterior*
A	65	35	30	25
B	70	35	35	30
C	50	35	30	25

It has been stated by Dr. Reeside that this is a new species aff. *Pinna lakesii* White. It differs from *Pinna lakesii* in its larger size, markings, and median surface.

Horizon and locality. Ten specimens from Frontier formation at the northwest end of Casper Mountain, Wyoming, three miles west of the narrows formed by the North Platte River. Holotype, Univ. Iowa, Pal. Mus. No. 7–455

Genus OSTREA Linné

OSTREA FRONTIERENSIS Sidwell, n. sp.

Plate 48, figures 3–6

Shell thin, valves close-fitting, height greater than length, subcircular to oval in outline and almost equivalve. Beaks centrally located, pointed, and obliquely inclined toward the right valve. Left valve convex, umbones small, beaks pointed, the outer border reflected and crenulate. Right valve deeply and broadly concave in central portion, the concavity bordered by a prominent submarginal ridge from which the surface slopes abruptly to meet and overlap the margin of the opposite valve. Contact line evenly sinuous. Margins of both valve thickened and showing a multiplication of the edges of the lamellose layers. Hinge-line short and straight. Posterior to the hinge-line is a trapezoidal ligament area, bordered laterally and apically by a depressed tract. A shallow narrow groove arises at the left terminus of the hinge-line and parallels the thickened border, dying out anterolaterally. Adductor scar prominent, depressed, and submarginal. The border ridge for a few millimeters beyond the hinge-line on either side bears several small low, angular corrugations arranged in a broad arc, about three to each millimeter. Right valve smooth. There are definite curved ridges and furrows, however, which extend obliquely across the shell. These appear to be accidental, since they look like impressed surface markings of some unknown shell. Structure of shell made of thin layers, the outer of which are nacreous and porcellanous. This form is represented by three specimens. Length of holotype, 15 mm.; height, 20 mm.

Horizon and locality. Two specimens from frontier formation three miles northeast of Medicine Bow, Wyoming, in sec. 35, T. 23 N., R. 78 W. Holotype, Univ. Iowa, Pal. Mus. No. 7–434.

Genus CRASSATELLITES Kruger

CRASSATELLITES WYOMINGENSIS Sidwell, n. sp

Plate 49, figures 1–5

Shell moderately thick, equivalve, subtrigonal, and slightly elongated. Valves thick, somewhat rostrate, of medium size, height and length about equal. Dorsal border declining sharply from the beaks, concave toward front and convex behind. In the concave surface anterior to the beaks is a heart-shaped, deep lunule; posterior to beaks is an elongated, narrow, rather shallow depression. Anterior margin roundly truncate on lower half of shell and sharply rounded where it meets the ventral border; ventral margin broadly convex; extending from umbones to posterior ventral margin is an elevated obtuse ridge whence the valves are noticeably deflected to the dorsal border. Beaks prominent, slightly incurved and located in advance to the middle. Hinge-line arched, hinge-plate strong and flat. The muscle scars are semioval, fairly deep, and connected by a simple pallial line. Surface ornamented by regular elevated lines of growth separated by furrows (umbonal slope of the concentric lines the steeper) about equal to elevations.

Fine lines are superimposed on the ridges. Posterior to the oblique ridges the coarse lines are much finer, more numerous, and deflected upward. This part of the shell appears almost bare to the naked eye. Height of shell, 30 mm.; length, 30 mm.; thickness, 15 mm.

Horizon and localities. Figured specimens from the Frontier formation at Casper Mountain three miles west of the narrows. Other locations, on the Lincoln highway seven miles east of the town of Rawlins; three miles northeast of Medicine Bow in Sec. 35, T. 23 N., R. 78 W., Como Ridge quadrangle. Holotype, Univ. Iowa, Pal. Mus. No. 7–458.

Genus MODIOLA Lamarck

MODIOLA THOMASI Sidwell, n. sp.

Plate 48, figures 7–10

Shell subovate elongate, moderately gibbous, length twice the height and equivalve. Beaks subterminal, depressed, inconspicuous, located at the anterior and thicker end of the shell, extending forward and forming a part of the anterior margin; their points are lower than the dorsal margin. Obtuse ridges extend diagonally from the umbones of the shell to the lower edge of the posterior margin. These ridges are strongest at midlength and their development is the outstanding feature of the shell. Dorsal margin convex in outline flattened just back of the umbones and cuneate behind. Ventral margin concave, slightly gaping, thickened anteriorly and constricted posteriorly. Anterior margin short extending slightly forward to the beaks and broadly rounded below. This form is an internal mold and represented by one specimen. Dimensions: Length, 10 mm.; height, 5 mm.; thickness, 5 mm.

Horizon and locality. One specimen from the Frontier formation three miles northeast of Medicine Bow, sec. 35 T. 23 N., R. 78 W., Como Ridge quadrangle.

Genus CORBULAMELLA Meek and Hayden

CORBULAMELLA WYOMINGENSIS Sidwell, n. sp.

Plate 48, figures 11, 12

Shell very small, extremely inequivalve, subglobose; right valve larger and more gibbous; umbones large. Anterior side rounded below; posterior side subtruncate at extremity; based broadly rounded usually more prominent to the anterior, beaks well separated, prominent, centrally located, that of right valve elevated over the other, both incurved with hinge-line. Surface marked with concentric lines of growth which are more prominent on the right valve; muscle scar or teeth undetermined. Length of average specimen, 2 mm.; height, 2 mm. This form is abundant but poorly preserved.

Horizon and localities. Figured specimens from Frontier formation at Medicine Bow, sec. 2, T. 22 N., R. 78 W., Como Ridge quadrangle. Other locations are seven miles east of the town of Rawlins and three miles west of the narrows of Casper Mountain. Holotype, Univ. Iowa, Pal. Mus., No. 7–452.

Class SCAPHOPODA

Genus CADULUS Phillips

CADULUS FRONTIERENSIS Sidwell, n. sp.

Plate 48, figure 13

Shell small, tubular, thin, curved, contracted at each end and swollen in advance to midlength. Aperture slightly oblique, minutely constricted; apex very small and slender. Posterior opening smaller than the oral. Surface polished and shining, without striae. Length of shell, 4 mm.; width of aperture, 0.67 mm. This specimen is preserved in a compact calcareous sandstone and represented by two specimens.

Horizon and locality. Frontier formation, three miles northeast of Medicine Bow in sec. 35, T. 23 N., R. 78 W., Como Ridge quadrangle. Holotype, Univ. Iowa, Pal. Mus., No. 8–629.

Class GASTROPODA

Genus ANISOMYON Meek and Hayden

ANISOMYON APICALIS Sidwell, n. sp.

Plate 48, figures 14, 15

Shell obliquely conical, preserved as a cast which has an irregular surface. Apex pointed, sharply elevated and situated posterior to the center; aperture subcircular. Posterior surface nearly vertical, but a line drawn from the apex to the margin is gently concave. Anterior surface moderately convex, provided with sharp, well defined median ridge extending from the apex to the margin, surface on either side of ridge depressed. Lateral margin of the cone gradually expanding. Surface marked by irregular approximately concentric lines of growth extending parallel to the base and best developed on lower portion of shell. Length of shell, 24 mm.; width at base, 20 mm. This species differs from *Anisomyon frontierensis* by the well-defined pointed apex and by the sharp ridge on the anterior surface.

Horizon and locality. Represented by one specimen from the Carlile formation at Casper Mountain three miles west of the narrows formed by the North Platte River.

ANISOMYON FRONTIERENSIS Sidwell, n. sp.

Plate 48, figures 16, 17

Shell medium size, broadly conical and with flaring margins. Apex elevated, pointed forward and located slightly anterior to the center. Anterior surface nearly straight with concave area immediately below the apex in well-preserved shells. Posterior surface gently rounded; sides of shell spreading broadly to the

EXPLANATION OF PLATE 48

FIGS. 1, 2—*Pinna reesidei* Sidwell, n. sp. 1, Holotype, fragment from larger end of specimen. 2, fragment view nearer the apex.

3–6—*Ostrea frontierensis* Sidwell, n. sp. 3, Drawing of left valve, ×1½; 4, left valve natural size; 5, drawing of right valve, ×1½; 6, right valve, ×1½.

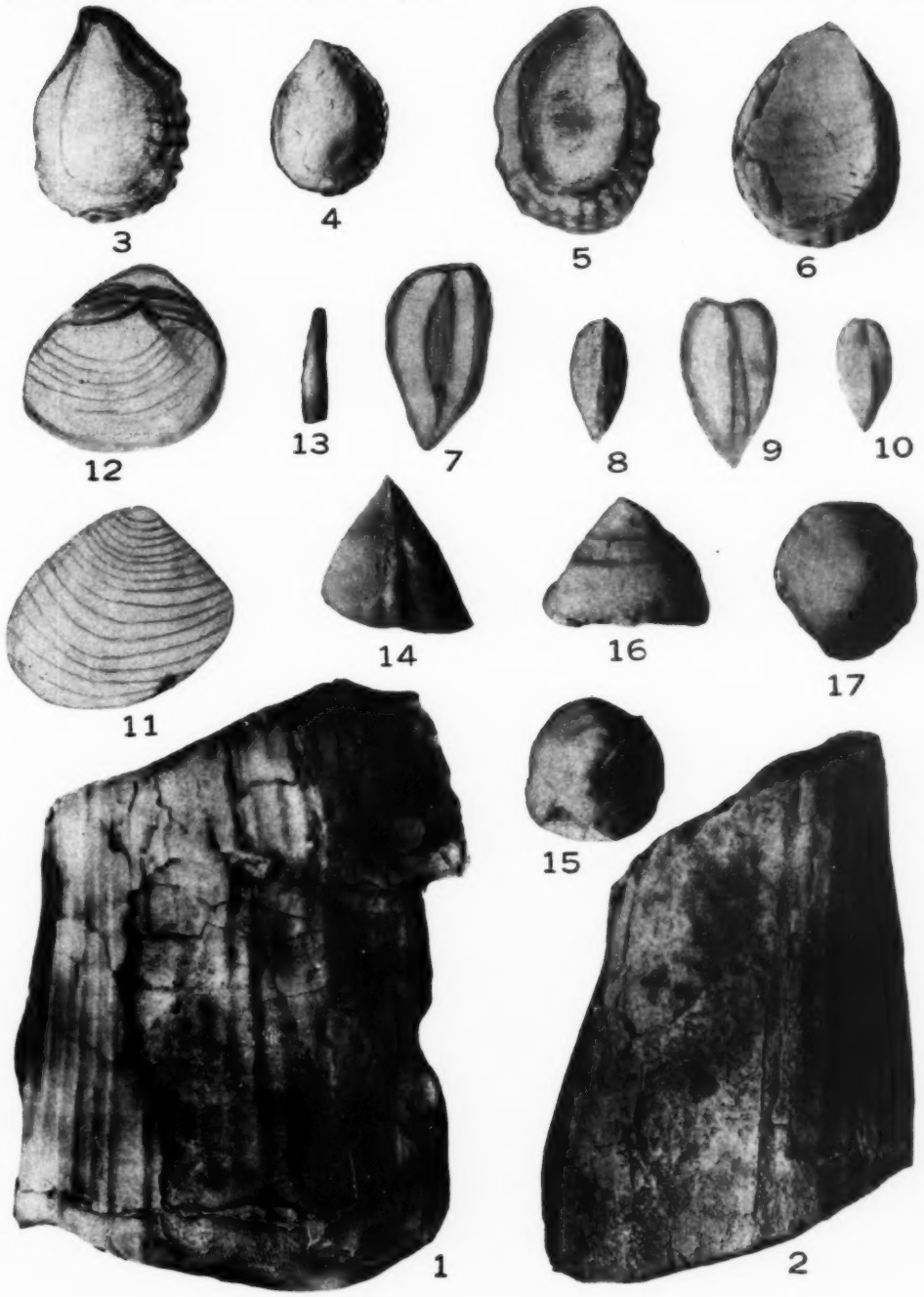
7–10—*Modiola thomasi* Sidwell, n. sp. 7, Drawing of ventral border, ×5; 8, ventral view, ×1½; 9, drawing of dorsal portion, ×5; 10, dorsal view of holotype, ×1½.

11, 12—*Corbulamella wyomingensis* Sidwell, n. sp. 11, Drawing of right valve, holotype, ×20; 12, drawing of left valve, paratype, ×20.

13—*Cadulus frontierensis* Sidwell, n. sp., 13 View showing tubular form, ×4.

14, 15—*Anisomyon apicalis* Sidwell, n. sp. 14, Anterior view showing ridge; 15, apical view.

16, 17—*Anisomyon frontierensis* Sidwell, n. sp. 16, Lateral view; 17, showing apex.



Sidwell, Cretaceous Molluska

base. Surface marked by coarse, irregular growth-lines, extending parallel to the margin; they are best developed on the lower half of the shell. Height of shell, 23 mm.; width at base, 22 mm.

Horizon and localities. Figured specimen from the Frontier formation at Medicine Bow, sec. 2 T. 22 N., R. 78 W., Como Ridge quadrangle. It is found at Casper Mountain three miles west of the narrows. Holotype, Univ. Iowa, Pal. Mus., No. 7–396.

Genus GYRODES Conrad

GYRODES NODOSUS Sidwell, n. sp.

Plate 49, figures 6, 7

Shell small to medium size, depressed subglobose, height about two-thirds the width and composed of four or five volutions which are nearly convolute and narrowly shouldered. Spire slightly elevated above body whorl; sutures shallow and bordered by a depression on shoulder of next whorl. Body whorl large, rapidly expanding and constituting about four-fifths the bulk of the shell. Aperture subovate, length twice the width, outer lip thin, its margin sloping obliquely downward and backward from shoulder. Umbilicus broad. Surface nearly smooth, but marked by obscure lines of growth. In the humeral depression there is a row of nodes or wrinkles whose longer axes are radially disposed. These nodes are most abundant on the body whorl and are strongest on outer border of the depression. Height of shell, 6 mm.; width, 9 mm.

This species differs from *Gyrodes crenata* Conrad in the smaller size of the shell, shape of the aperture, and the absence of the conspicuous nodes that surround the umbilicus.

Horizon and localities. Figured specimens from the Frontier formation on Lincoln highway seven miles east of Rawlins. Other locations, sec. 35, T. 23 N., R. 78 W., Como Ridge quadrangle, Casper Mountain, three miles west of the narrows. Holotype, Univ. of Iowa, Pal. Mus., No. 7–399.

Genus LUNATIA Gray

LUNATIA EDNAE Sidwell, n. sp.

Plate 49, figures 8, 9

Shell large, lustrous, semiglobose, umbilicate, obliquely subovate, spire low and made of about four closely coiled convex volutions which are partially convolute. Body whorl large, sides rounded, increasing rapidly in width and thickness. Sutures narrow, deeply impressed and bordered below by a shallow rounded groove. Umbilicus fairly large and open. Aperture ovate, straighter on the inner than on the outer side and facing obliquely downward. Outer lip thin, entire, extending obliquely backward from the upper portion of the volution. Inner lip thickened by a callus. Surface apparently smooth and glossy, but ornamented by rather fine lines of growth. Apical angle 120 degrees (average of three specimens). Dimensions of average specimen: height, 14 mm., width, 22 mm.; length of aperture, 12 mm., width, 9 mm. This species is abundant and of many sizes.

Horizon and localities. Figured

specimens from the Frontier formation two miles northeast of Medicine Bow in sec. 2, T. 22 N., R. 78 W., Como Ridge quadrangle. It also occurs in the Frontier formation at Casper Mountain two miles west of the narrows made by North Platte River, and on the Lincoln highway seven miles east of Rawlins. Holotype, Univ. of Iowa, Pal. Mus. No. 7–414.

Class CEPHALOPODA

Genus PRIONOCYCLUS Meek

PRIONOCYCLUS REESIDEI Sidwell, n. sp.

Plate 49, figures 10–12

Shells show variety of sizes from 35 to 180 mm. in diameter. They are discoidal in outline, periphery flattened and provided with a narrow, prominent serrated mesial keel which increases in size with growth. The keel on the body whorl of the small specimen is 2 mm. in height, and 1.5 mm. wide. Early volutions apparently more or less circular in cross-section but at a diameter of 15 or 20 mm. they become subquadrate and continue so throughout. Inner portion of shell closely embraced, outer volutions in large shell in contact but not so tightly coiled as in youth. Lateral parts of the early volutions well exposed in the wide umbilicus. Septa little known; evidence at hand show them to be prionocyclid in character. Surface ornamented with prominent ridges which increase in size and strength from earlier stage of shell to aperture. On the larger portion of the shell each rib bears two nodes, one in the early stages on the umbilical margin but in the later stages the inner node almost half way out from the umbilical margin to the ventro-lateral margin, the other on the ventro-lateral margin where the rib bends sharply forward. The first on the early shell appear on the outer margin of the volution, beyond this for one-half to three-fourths volution the nodes are irregularly arranged; for the remainder of the shell each rib contains two increasingly larger nodes. This form differs from *Prionocyclus wyomingensis* in the stronger ribs and the arrangement of the nodes.

Horizon and localities. Figured specimens from the Frontier formation on the Lincoln highway seven miles east of Rawlins. Other locations, at Medicine Bow, in sec. 35, T. 23 N., R. 78 W., Como Ridge quadrangle, at Casper Mountain three miles west of the narrows. Holotype, Univ. of Iowa, Pal. Mus., No. 8–616.

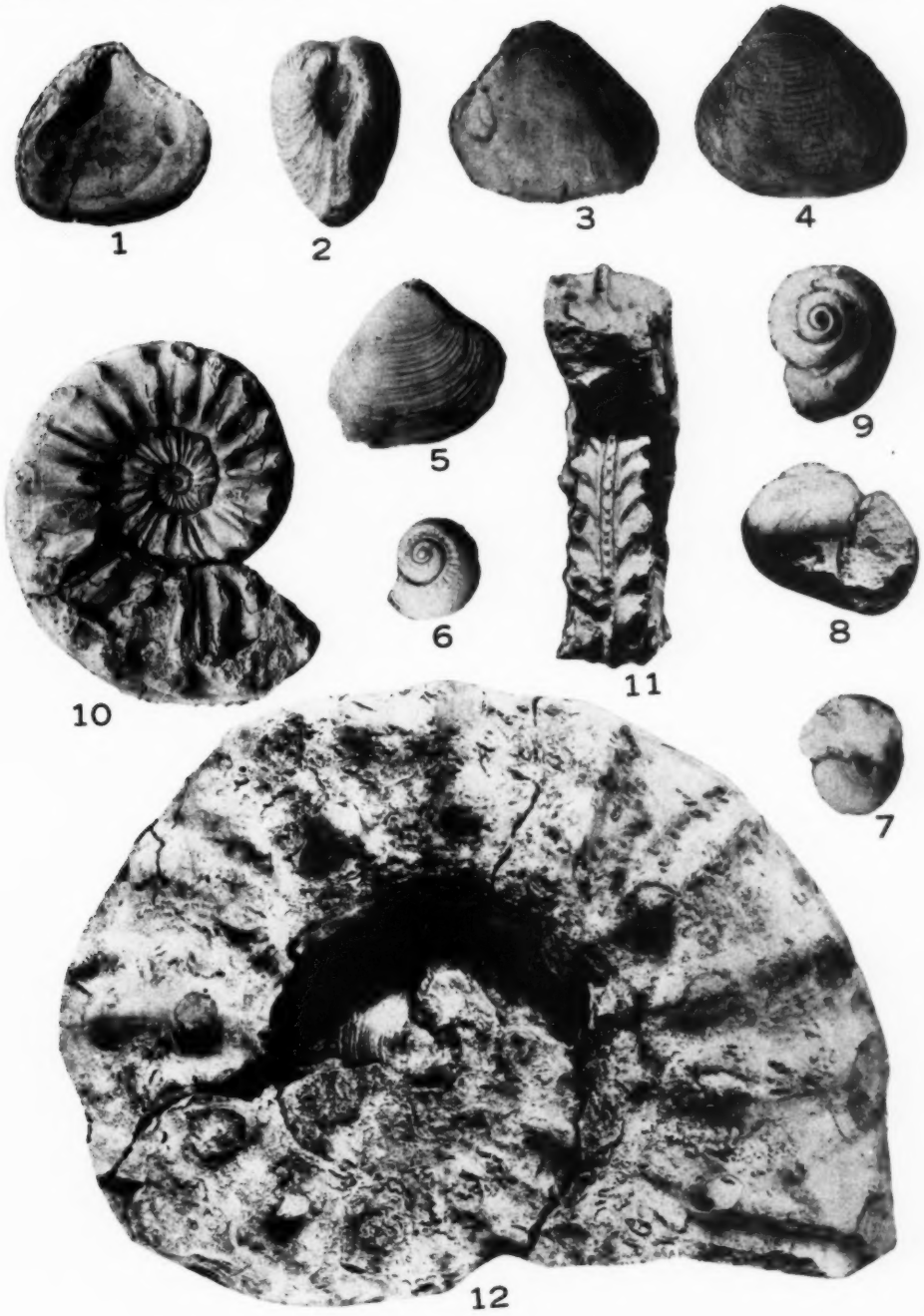
EXPLANATION OF PLATE 49

FIGS. 1–5—*Crassatellites wyomingensis* Sidwell, n. sp. 1, Interior of shell; 2, anterior margin; 3, cast showing muscle scars; 4, left valve (holotype); 5, right valve. 1–3, 5, paratypes.

6, 7—*Gyrodes nodosus* Sidwell, n. sp. 6, Apical view of holotype; 7, aperture of paratype, ×2.

8, 9—*Lunatia ednae* Sidwell, n. sp. 8, Apertural view of holotype; 9, apical view of paratype.

10, 12—*Prionocyclus reesidei* Sidwell, n. sp. 10, Lateral view of holotype; 11, peripheral view of holotype showing keel; 12, fragment of a large paratype.



Sidwell, Cretaceous Molluska

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NOTES ON THE ANNONA CHALK

NORMAN L. THOMAS AND ELMER M. RICE[1]
Forth Worth, Texas

ABSTRACT

The Annona or Pecan Gap chalk is of middle Taylor age. It lies normally on Ozan or Wolfe City clays and sands and beneath Marlbrook or upper Taylor marls and sands. In faunal characters it is intermediate between the Gober chalk of the lower Taylor and the Saratoga chalk of the upper Taylor.

INTRODUCTION

The chalk beds that outcrop at White Cliffs, Sevier County, Arkansas, at Clarksville (northwest of Annona), Red River County, Texas, and at Pecan Gap, Delta County, Texas, have been shown by Miss Ellisor to be approximately contemporaneous. It is unfortunate that the name White Cliffs is preoccupied for the best outcrop occurs at this place. However, it is generally considered the original locality, and therefore the type for the division. The name Annona has been chosen for these beds, although the outcrop of the chalk is some miles to the northwest of Annona in the vicinity of Clarksville. The term Pecan Gap has also been applied to the chalk beds. Pecan Gap is an excellent locality, the outcrop lies within half a mile of the railway station, and the name is not preoccupied. The chalk then may be considered as having two names and three type localities. White Cliffs is doubtless the original locality, Annona the first valid name, and Pecan Gap the most appropriate of the three, but limited to an upper chalk phase of the Annona. Our studies have been based on all three of the named localities. We consider these outcrops to represent approximately contemporaneous sedimentation making them parts of the same chalk formation, and the fossils confirm lithologic field evidence. By this we do not mean that the thin section at Pecan Gap is equivalent to the completer chalk section at White Cliffs. There are many instances in which, due to different rates of deposition, a thin bed in one place is the time equivalent of a thick bed in another, but this does not appear to be the condition in the example here. The three outcrops belong in the middle or upper-middle Taylor and are approximately time equivalents, the White Cliffs outcrop probably having a greater time range than the other two and probably containing the whole time equivalents of both the Annona (Clarksville) and the Pecan Gap outcrops. It is correct to call the Pecan Gap chalk a tongue of

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the Annona chalk of White Cliffs, but it is very difficult to separate the Pecan Gap from the rest of the Annona in subsurface work, even with the aid of fossils. Accordingly, it seems that the use of one name would cause less confusion. Some writers use Annona to include shales and sands in this part of the Taylor, but it is customary to use Pecan Gap to include only the chalk phase. Shales equivalent to upper Pecan Gap chalk are very similar to Marlbrook marls in faunal character, while sands and sandy shales equivalent to the Marlbrook contain an assemblage quite different from typical Marlbrook marl.

WHITE CLIFFS LOCALITY

The "White Cliffs chalk" outcrops in a bluff overlooking Little River at the White Cliffs Portland Cement Works in Sevier County, Arkansas. According to Taff, the upper part of the bluff is composed of 60 feet of massive, creamy, white chalk and the middle of 25 feet of dull, bluish-white, siliceous chalk slightly harder than the pure chalk above. The lower 50 feet of the bluff is composed of marly chalk, becoming sandy toward the bottom. Dane considers the two upper divisions as the Annona chalk, and the lower 50 feet as Ozan, a zone between containing chalk-filled borings. We are not in a position to dispute this view but we have considered the whole cliff down to the water's edge, during normal stage of the river, as Annona, and the sandy material seen at the very base of the cliff, occasionally during low water as Ozan. It does seem possible that the sandy base of the thin Pecan Gap locality may be equivalent approximately to the White Cliffs "chalk-filled borings horizon" but this does not prove that the Ozan includes the lower marly chalk at White Cliffs. If this is the case there must be a considerable hiatus at the base of type Pecan Gap, or the Wolfe City sand underneath the chalk must be correlated with the lower marly chalks at White Cliffs.

ANNONA LOCALITY

Outcrops north, east, and southeast, and within the city of Clarksville, Red River County, Texas, may be considered those of the locality from which the Annona chalk takes its name, since at the town of Annona the chalk is covered by upper Taylor marls. Exposures of chalk are not connected and relatively few feet of vertical section are exposed at any one place. Therefore, it is difficult to arrange samples in stratigraphic order.

PECAN GAP LOCALITY

About half a mile west of the railroad station of Pecan Gap, Delta County, Texas, there is an excellent outcrop of chalk extending along the railway cut and up into nearby fields. The whole thickness of chalk from sandy shales and *Baculite*-bearing conglomeratic chalk at the base to marls at the top is represented at this one locality. The vertical section of chalk is not as thick as that previously described at White Cliffs nor does it represent as great an interval

of time. Sands and sandy shales at the base are called Wolfe City sands, from a town on an outcrop of this sand a few miles to the southwest. The Pecan Gap chalk probably represents the middle of the White Cliff section, not beginning as early in the time scale represented by the marly chalks at the base of the cliff and not extending as late into Taylor time as the uppermost chalk at White Cliffs. The Pecan Gap fauna is like the middle and upper White Cliffs fauna but the lower White Cliffs assemblage is not characteristically represented unless in a very thin horizon at the base. Due to the arrangement of fossil assemblages and to the thinness of the outcrop it seems reasonable to suppose that the base of the chalk at Pecan Gap is not equivalent to the "water's edge" base at White Cliffs but is probably up in the cliff, possibly at the "chalk-filled boring horizon" as previously suggested. We must keep in mind that conditions during Upper Cretaceous deposition in Texas were not sufficiently uniform for the base of a chalk at one place to be equivalent exactly to the base of that chalk at another, nor for tops of a chalk everywhere to represent the same place in the time scale. Sands can be correlated with chalks only with great difficulty. While there is a suggestion of a break in sedimentation at the "chalk-filled boring horizon" and a decided change in sedimentation at the base of the Pecan Gap chalk, it is not necessarily true that this seeming coincidence proves that they correlate, even though the faunas roughly suggest some such correlation.

THE OUTCROP

Annona chalk is known to occur in a line of discontinuous outcrops in Arkansas, passing Yancy, north of Saratoga, through White Cliffs and Rocky Comfort, southwest of Foreman; and in Texas through Clarksville, Pecan Gap, Farmersville, and Rockwall. This chalk is not as hard as Austin chalk and does not give as much relief to the country, and in no place presents anything comparable to the escarpment which the Austin chalk produces at Dallas, Hillsboro, Waco, and other places. The chalk is fairly soft, having a "flour character" both in appearance and to the touch. Indeed, it may be considered a "lime flour" whose crystals are so fine that they are not apparent without the aid of considerable magnification. There is considerable silt intimately mixed with the calcium carbonate and possibly a small amount of volcanic ash. The silt aids in giving the soft "flour character." Anamorphism has acted very mildly on this chalk and the material has not become indurated or coarsely crystalline. It is capable of making true limestone as shown by limestone effects in fault zones.

SUBSURFACE DISTRIBUTION

Wells in southwestern Arkansas, northwestern Louisiana, and northeastern Texas encounter the Annona chalk and drillers are accustomed to use this chalk for their first reliable

and persistent marker. Generally speaking, the base of the chalk is more consistent than the top of the chalk although either the top or the bottom is serviceable for contour work because they both reflect structural conditions. It is not necessary to know that the top or bottom of a bed is exactly the same age over its whole outcrop. Such is practically never the case with the Cretaceous chalks of the Gulf Coast. Instead, one needs to know that changes in the correlation horizon are regular, consistent, and gradual so that within any local area the bed is practically the same and over wide areas its change is so gradual that its vertical (age) variation will be negligible.

In many places drillers log an exceptionally thick chalk and probably include the Gober with the Annona at times. However, the subsurface chalk is thicker than the chalk on the outcrop and in many areas probably includes much more section than the outcropping chalk. The Wolfe City sands, immediately below, are present in some areas but appear to be undeveloped in others. Basal Annona, in places, contains a few feet of chalk similar to the "Orbulina rock" discussed by Mrs. Plummer in Bulletin 3101 of the University of Texas. This type of rock is common in the Georgetown limestone and is imitated by certain phases of the Austin chalk. We have considered these spherules as oolitic in origin and were very much interested to know that Mrs. Plummer by a much more thorough study has arrived at the same conclusion. This "orbuline," "spherical body," "oolitic" character should not be confused with globigerine development, from which it is distinct. The likeness in abundance and characters of spherules in the Georgetown, Austin, and Annona-Pecan Gap has caused confusion in certain determinations. We are not certain that the Annona and Austin phases can be separated by a study of thin-sections. We believe that in most cases, by using great care and preparing several sections, they can be separated from the Georgetown with the aid of fossil content, but not by use of the spherules alone.

Although the Annona chalk has a thickness of 200 to 400 feet or more in Harrison, Upshur, Wood, and Van Zandt Counties, Texas, it thins rapidly and disappears in Kaufman County and is unknown westward except for a few spasmodic occurrences. In Falls and Bell counties the Marlin and Lott chalks probably are equivalent to parts of the Annona section.

We have suggested that the sands at the base of the White Cliffs bluff may not be equivalent to the Wolfe City sands developed around Pecan Gap and Wolfe City because the thickness of the lower chalk phase is much greater at White Cliffs than on the outcrops at Pecan Gap. In subsurface correlation we have, therefore, inconsistently used the term Wolfe City sand for every sandy section below the continuous chalk body, irrespective of thickness of lower chalk. The lower chalk is generally thicker in the central part of the east Texas geosyncline than at

White Cliffs outcrop. One can follow this sandy phase from Wolfe City south into the basin and if the definition of Wolfe City sand is that sandy series underlying the Annona chalk irrespective of basal thickening or exact time equivalency, there is little confusion.

Through the upper part of the subsurface chalk there is a zone characterized by an abundance of certain fossils such as *Bolivinoides decorata* and *Cibicides excolata* and this "*decorata-excolata* zone," as it may be called, is distinctly upper Annona in age, and includes most of the Pecan Gap type section and the upper two-thirds of the White Cliffs outcrop. It appears that wells in east Texas usually encounter a section more like the White Cliffs section than the one at Pecan Gap. If the lower 50 feet at White Cliffs must be called Ozan, then the lower Annona chalk in many of the east Texas counties must be called Ozan. Its contact with true Pecan Gap above cannot be distinguished easily and this division is not useful in subsurface work. A formation is not necessarily delimited at both its base and top by diastems or unconformities nor does a formation necessarily exclude by definition all depositional breaks or times of local erosion.

We wonder whether it is better to consider the base of the Annona chalk as the "chalk-filled boring horizon" at White Cliffs, the base of the chalk at Pecan Gap, and the base of abundant "*decorata-excolata*" fauna in the midst of the chalk in wells; or whether it is better to recognize that the base of the chalk varies in age, and in spite of this, use this base as the bottom of the Annona chalk. We do practically the same thing without question with the top of this chalk. Most workers recognize that the top of the chalk varies greatly in stratigraphic position and yet the top is seldom questioned. It is important to recognize refined correlations but we must keep our geologic column defined so that all workers may use terms without undue confusion.

A Few Wells Having Annona Chalk

State	County-Parish	Farm and Well	Company	Top Chalk
Arkansas	Union	Gaddy 1	Pure Oil Co.	2440
Arkansas	Little River	Arden 1	H. L. Grote	228
Louisiana	Sabine	Wilson 1	Loring	3233
Louisiana	Natchitoches	Collins 1	Coates	2278
Texas	Bowie	Thompson 1	Boyd	1546
Texas	Cass	Citizens Bank 1	Texas Oil Co.	2363
Texas	Harrison	Key 1	Ryan Consolidated	1968
Texas	Shelby	Carraway 1	Gulf	1715
Texas	Sabine	Mills 1	Benedum & Trees	3000
Texas	Rusk	Holland 4	Sinclair	2624
Texas	Upshur	Wade 1	Amerada	2221
Texas	Smith	Christian 1	Amerada	3224
Texas	Van Zandt	York 5	Pure	1530
Texas	Henderson	Schaunessy 1	Bradstreet	2560
Texas	Anderson	Moody 1	Roeser	2976

Note: This table was compiled from literature and well logs, as well as from our own determinations.

The previous discussion may leave the erroneous impression that abundant *Bolivinoides decorata* and *Cibicides excolata* and their associated forms are limited to the upper Annona chalk. However, this characteristic faunal facies continues through Marlbrook even into Saratoga time, as we have shown in a previous paper. Also, it should be noted that *B. decorata* and *C. excolata* occur occasionally in the lower Annona chalk, have been reported from the lower part of White Cliffs and even in shales which have been considered Ozan.

MACRO-FOSSILS OF THE ANNONA CHALK

The following list of macro-fossils of the Annona chalk is compiled from literature.

Coral
Hemiaster (?)
Echinocorys cf. *texana* (Cragin)
Echinoid of family *Spatangidae*
Cidaris (?)
Serpula sp.
Hamulus onyx Morton
Hamulus squamosus Gabb
Inoceramus aff. *barabini* Morton
Ostrea plumosa Morton
Ostrea falcata Morton
Ostrea panda Morton
Gryphaeostrea vomer (Morton)
Gryphaea sp.
Gryphaea vesicularis Lamarck, var.
Exogyra ponderosa Roemer
Exogyra ponderosa var. *erraticostata*
Trigonia sp.
Pecten sp.
Pecten casteeli Knicker
Lima sp.
Paranomia sp.
Spondylus sp.
Rudistid fragments
Veniella sp.
Cordium sp.
Solyma (?)
Legumen sp.
Gyrodes sp.
Monodonta sp.
Anchura sp. (Large)
Anchura sp. (Small)
Tudicla sp.
Turritella sp.
Volutoderma sp.
Morea cancellaria Conrad
Actaeon sp.
Eutrephoceras sp.
Nostoceras sp.
Pachydiscus sp.
Baculites ovatus Say
Baculites asper Morton
Baculites sp.
Hamites (?)
Corax falcatus Agassiz
A vertebra

The following lists of micro-fossils are based on collections made by the writers and identifications by Doctor Cushman. The White Cliffs list is incomplete.

COMMON FORAMINIFERA OF THE ANNONA CHALK

Lituola taylorensis Cushman and Waters
Spiroplectammina laevis (Roemer)
Textularia ripleyensis W. Berry
Gaudryina chapmani Franke
Gaudryina oxycona Reuss
Gaudryina stephensoni Cushman
Gaudryina pupoides d'Orbigny
Gaudryina laevigata Franke, var. *pyramidata* Cushman
Heterostomella foveolata (Marsson)
Clavulina amorpha Cushman
Clavulina trilatera Cushman
Clavulina plummerae Sandidge
Arenobulimina presli (Reuss)
Robulus münsteri (Reuss) ?
Lenticulina rotulata Lamarck
Marginulina intermedia (Philippi)
Planularia tricarinella (Reuss)
Dentalina megalopolitana Reuss
Dentalina aculeata d'Orbigny
Saracenaria italica DeFrance

Frondicularia archiciana d'Orbigny
Frondicularia archiciana d'Orbigny, var. *strigillata* Bagg.
Frondicularia goldfussi Reuss
Flabellina interpunctata von der Marck
Kyphopyxa christneri (Carsey)
Lagena acuticosta Reuss
Globulina prisca Reuss
Globulina lacrima Reuss, var. *horrida* Reuss
Globulina lacrima Reuss
Oolina sp.
Gümbelina globulosa (Ehrenberg)
Gümbelina striata (Ehrenberg)
Gümbelina tessera (Ehrenberg)
Gümbelina sp.
Bolivinoides decorata (Jones) var. *delicatula* Cushman
Bolivinita eleyi Cushman
Eouvigerina americana Cushman
Eouvigerina americana Cushman, var.
Pseudouvigerina cretacea Cushman
Buliminella carseyae Plummer
Bulimina murchisonana d'Orbigny
Bolivina incrassata Reuss
Loxostomum clavatum (Cushman)
Pleurostomella subnodosa Reuss
Gyroidina umbilicata (d'Orbigny)
Gyroidina compressa (Alth)
Gyroidina micheliniana (d'Orbigny)
Pulvinulinella alata (Marsson)
Pullenia quinqueloba Reuss
Pullenia quaternaria (Reuss)
Globigerina cretacea d'Orbigny
Globigerinella asper (Ehrenberg)
Globotruncana canaliculata (Reuss)
Globotruncana conica White
Globotruncana arca (Cushman)
Anomalina complanata Reuss
Anomalina involuta (Reuss)
Anomalina rubiginosa Cushman
Anomalina pertusa (Marsson)
Planulina taylorensis (Carsey)
Cibicides excolata (Cushman)
Cibicides involuta (Reuss)

FORAMINIFERA ABUNDANT AT WHITE CLIFFS, ARKANSAS

Spiroplectammina laevis (Roemer)
Gaudryina oxycona Reuss
Gaudryina pupoides d'Orbigny
Heterostomella foveolata (Marsson)
Clavulina trilatera Cushman
Robulus münsteri (Reuss) ?
Lentinculina rotulata Lamarck
Marginulina intermedia (Philippi)
Saracenaria italica DeFrance
Dentalina megalopolitana Reuss
Dentalina aculeata d'Orbigny
Frondicularia archiciana d'Orbigny
Lagena acuticosta Reuss
Oolina sp.
Gümbelina sp.
Gümbelina striata (Ehrenberg)
Gümbelina tessera (Ehrenberg)
Gümbelina globosa (Ehrenberg)
Bolivinoides decorata (Jones)
Bulimina murchisonana d'Orbigny
Buliminella carseyae Plummer
Bolivina incrassata Reuss
Pleurostomella subnodosa Reuss
Gyroidina micheliniana (d'Orbigny)
Gyroidina compressa (Alth)
Globotruncana conica White
Globotruncana arca (Cushman)
Globotruncana canaliculata (Reuss)
Globigerina cretacea d'Orbigny
Globigerinella asper (Ehrenberg)
Anomalina complanata Reuss
Anomalina rubiginosa Cushman
Anomalina pertusa (Marsson)
Planulina taylorensis (Carsey)
Cibicides excolata (Cushman)
Cibicides involuta (Reuss)

FORAMINIFERA ABUNDANT IN THE CHALK AT CLARKSVILLE, (NEAR ANNONA), TEXAS

Spiroplectammina laevis (Roemer)
Textularia ripleyensis W. Berry
Gaudryina chapmani Franke
Gaudryina oxycona Reuss
Heterostomella foveolata (Marsson)
Clavulina trilatera Cushman
Clavulina amorpha Cushman
Arenobulimina presli (Reuss)
Robulus münsteri (Reuss)?
Lenticulina rotulata Lamarck
Marginulina intermedia (Philippi)
Dentalina aculeata d'Orbigny
Dentalina megalopolitana Reuss
Saracenaria italica DeFrance
Nodosaria sp.

Frondicularia archiciana d'Orbigny
Frondicularia goldfussi Reuss
Kyphopyxa christneri (Carsey)
Oolina sp.
Lagena acuticosta Reuss
Globulina lacrima Reuss
Gümbelina striata (Ehrenberg)
Gümbelina sp.
Gümbelina tessera (Ehrenberg)
Gümbelina globulosa (Ehrenberg)
Bolivinita eleyi Cushman
Bolivinoides decorata (Jones)
Eouvigerina americana Cushman
Pseudouvigerina cretacea Cushman
Bulimina murchisonana d'Orbigny
Buliminella carseyae Plummer
Loxostomum clavatum (Cushman)
Pleurostomella subnodosa Reuss
Gyroidina umbilicata (d'Orbigy)
Gyroidina compressa (Alth)
Gyroidina micheliniana (d'Orbigny)
Pullenia quaternaria (Reuss)
Globigerina cretacea d'Orbigny
Globigerina sp.
Globigerinella asper (Ehrenberg)
Globotruncana arca (Cushman)
Globotruncana canaliculata (Reuss)
Anomalina complanata Reuss
Anomalina rubiginosa Cushman
Anomalina pertusa (Marsson)
Planulina taylorensis (Carsey)
Cibicides excolata (Cushman)
Cibicides involuta (Reuss)

FORAMINIFERA ABUNDANT IN THE CHALK AT PECAN GAP, TEXAS

Lituola taylorensis Cushman and Waters
Spiroplectammina laevis (Roemer)
Textularia ripleyensis W. Berry
Gaudryina oxycona Reuss
Heterostomella faveolata (Marsson)
Clavulina trilatera Cushman
Clavulina sp.
Arenobulimina presli (Reuss)
Robulus münsteri (Reuss)?
Lenticulina rotulata Lamarck
Marginulina intermedia (Philippi)
Planulina tricarinella (Reuss)
Frondicularia archiaciana d'Orbigny
Flabellina interpunctata von der Marck
Kyphopyxa christneri (Carsey)
Oolina cf. *emaciata* (Reuss)
Oolina sp.
Lagena acuticosta Reuss
Globulina lacrima Reuss
Gümbelina tessera (Ehrenberg)
Gümbelina globulosa (Ehrenberg)
Bolivinoides decorata (Jones) var. *delicatula* Cushman
Eouvigerina americana Cushman
Pseudouvigerina cretacea Cushman
Bulimina murchisonana d'Orbigny
Buliminella carseyae Plummer
Pleurostomella subnodosa Reuss
Gyroidina umbilicata (d'Orbigny)
Gyroidina compressa (Alth)
Gyroidina micheliniana (d'Orbigny)
Pulvinulinella alata (Marsson)
Pullenia quarternaria (Reuss)
Pullenia quinqueloba Reuss
Globigerina cretacea d'Orbigny
Globotruncana arca Cushman
Globotruncana canaliculata (Reuss)
Anomalina complanata Reuss
Anomalina pertusa (Marsson)
Anomalina rubiginosa Cushman
Planulina taylorensis (Carsey)
Cibicides excolata (Cushman)
Cibicides involuta (Reuss)

We are pleased that so many are taking an interest in these chalk studies as shown by letters commenting on our Saratoga notes. The most serious and persistent adverse criticism concerns the lack of definite and sweeping conclusions. We have felt that more data are necessary before authoritative correlations can be recorded or any formation names can be defined permanently. Our contribution will probably be greater in presenting facts than in trying to revise an Upper Cretaceous nomenclature which has been serviceable. It is planned to include data from these letters at a later time and we are hoping that enough information will be received to correct our ideas

and make published correlations more accurate.

The Annona chalk is a formation in the middle Taylor which illustrates characteristic chalk lensing on a large scale. The fauna is Taylor and is closely related to and intermediate between that of Marlbrook, upper Taylor, and Saratoga above; and Ozan, Gober, and lower Taylor below. Most of the foraminiferal species have been described, and a surprising number of these are European, according to Dr. Cushman's companion paper. While all of the fossils listed in this paper were taken from surface outcrops in the neighborhood of the three "type localities," most of these species are known to occur in the chalk encountered by wells.

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THE FORAMINIFERA OF THE ANNONA CHALK[1]

JOSEPH A. CUSHMAN
Sharon, Massachusetts

ABSTRACT

The foraminifera of the Annona chalk and the Pecan Gap tongue of the Annona show very close relationships to the Upper Cretaceous chalk faunas of Europe and also to some of the other chalk faunas of America. A number of species which have already been recorded from the Saratoga chalk occur in one or both of these others. Many of the Saratoga chalk species are not present, and numerous species of the Pecan Gap tongue and the main body of the Annona chalks are not present in the Saratoga. The accompanying paper describes some of these species not included in the preceding paper, and gives notes on their ranges.

In a preceding paper[2] I have described and figured the foraminiferal fauna of the Saratoga chalk from its type locality at Saratoga, Arkansas. The present paper takes up those species found in the Pecan Gap tongue and the main body of the Annona chalk at their type localities. In order to avoid repetition and to shorten this contribution, references are made to the description of the Saratoga chalk fauna already mentioned, and to another recent paper entitled "A Preliminary Report on the Foraminifera of Tennessee."[3] The latter paper has many excellent illustrations of species which occur also in these chalks, and references are made to those figures to avoid the necessity and expense of refiguring them here.

As noted already in the Saratoga chalk discussion, the faunas of these other chalks, as well as of the Upper Cretaceous series in general of Texas and related regions, are very similar to those of equivalent formations in Europe. Nearly all the species have already been described and figured.

Since this paper was completed, a summer has been spent studying European Cretaceous collections. The results of these studies are not yet in final form, but they show that our understanding of the earlier species described from Europe is subject to much revision. The earlier figures are often very small and poor, but types and topotype material have given a very clear understanding of many of these species, notes on which are being prepared for publication. The results of these studies serve to confirm the idea that the Upper Cretaceous Foraminifera of Europe and America are very closely allied and identical in many species.

[1] Published by permission of the Director of the U. S. Geological Survey.

[2] Cushman, J. A., The Foraminifera of the Saratoga Chalk, *Jour. Paleo.*, vol. 5, no. 4, December, 1931, pp. 297–315, pls. 34–36.

[3] Cushman, J. A., *Tenn. Division of Geology*, Bull. 41, 1931, pp. 1–116, pls. 1–13.

DESCRIPTION OF SPECIES

Family LITUOLIDAE

Genus LITUOLA Lamarck, 1804

LITUOLA TAYLORENSIS Cushman and Waters

Lituola taylorensis CUSHMAN AND WATERS, *1929*, Contr. Cushman Lab. Foram. Res., vol. 5, p. 66, pl. 10, figs. *7a–c*.—REITER, *1930*, Bull. Am. Assn. Petroleum Geol., vol. 14, p. 323.

Test large, compressed, most of the test planispirally coiled and involute; later chambers in the adult uncoiled, chambers labyrinthic, numerous, the number in the coil varying greatly in the microspheric and megalospheric forms, and in the young and adult stages; sutures distinct, slightly depressed; wall coarsely arenaceous but with a large amount of cement and smoothly finished on the exterior, very firmly cemented; aperture in the earliest stages at the base of the apertural face, quickly passing to the central portion of the apertural face and becoming multiple, in the uncoiled adult becoming terminal and the various openings taking up a large portion of the face. Maximum length, 5.00 mm.; breadth, 3.75 mm.; thickness, 1.25 mm.

This large species has a rather definite range in the general Taylor marl of Texas. It is a large, heavy species, and is subject to very considerable variation.

The species occurs at the type locality of the Pecan Gap chalk. It is very abundant at the type locality of the species, the upper part of the Taylor marl from Marquez Dome, Leon County, Texas, and occurs often in great numbers in equivalent horizons in well samples.

Family TEXTULARIIDAE

Genus SPIROPLECTAMMINA Cushman, 1927

SPIROPLECTAMMINA LAEVIS (Roemer)

Textularia laevis Roemer, Verstein. Norddeutsch. Kreide, p. 97, pl. 15, fig. 17, 1840–1841.

Textularia semicomplanata Carsey, Univ. Texas Bull. 2612, p. 25, pl. 3, fig. 4, 1927.

Spiroplectammina semicomplanata Plummer, Univ. Texas Bull. 3101, p. 129, pl. 8, figs. 7, 8, 1931.

Textularia sagittula, var. *coonensis* W. Berry, in Berry and Kelley, Proc. U. S. Nat. Mus., vol. 76, Art. 19, p. 3, pl. 2, fig. 3, 1929.

Spiroplectammina anceps Cushman and Church (not Reuss), Proc. Calif. Acad. Sci., ser. 4, vol. 18, p. 500, pl. 36, figs. 1, 2, 1929.—Cushman, Journ. Pal., vol. 5, p. 299, pl. 34, figs. 2*a*, *b*, 1931; Bull. 41, Tenn. Geol. Survey, p. 18, pl. 1, figs. 5*a*, *b*, 1931.

A study of three series of specimens identified by Reuss from his type locality shows that his *Textularia anceps* is not well figured, but has very distinctive characters in the specimens, as will be noted in a later paper. It is not the same as our common species of the Taylor and Lower Navarro which is identical with Roemer's species from the lower chalk of Peine, from which topotype material was studied. The species is close to *Textularia baudouiniana* d'Orbigny, but topotype material of this species shows it to be different from the one under discussion. This species has already been noted in the Saratoga Chalk paper. It is widely distributed in the lower part of the Navarro formation and in the Taylor Marl of Texas, and occurs in both the

Pecan Gap tongue and in the main body of the Annona Chalk.

Genus TEXTULARIA Defrance, 1824

TEXTULARIA RIPLEYENSIS W. Berry

Textularia ripleyensis W. BERRY, *1920*, in Berry and Kelley, Proc. U. S. Nat. Mus., vol. 76, Art. 19, p. 4, pl. 2, fig. 2.—CUSHMAN, *1931*, Tenn. Geol. Survey, Bull. 41, p. 19, pl. 1, figs. 6, 7.

Test compressed, slightly longer than broad, the apertural end broadly rounded, greatest width slightly above the middle, periphery subacute, serrate or only slightly lobed; chambers distinct, the outer end raised and depressed below, the raised portion usually roughened and the depressed portion smooth; sutures made distinct by the depressed areas but the sutural lines indistinct, nearly straight or slightly curved at the peripheral ends; wall roughened at the outer edge, smoother toward the base, distinctly arenaceous; aperture a very low opening in the median portion of the inner margin of the chamber with an elongate lobe at each side. Length up to 0.45 mm.; breadth, 0.35 mm.; thickness, 0.15 mm.

This species occurs in both the Pecan Gap tongue and in the main body of the Annona chalk, and is widely distributed in the Taylor marl of Texas and contemporaneous deposits in adjacent regions. Specimens of this species have been figured in the Tennessee report. It is subject to some variation in different parts of the section, but in general the characters are fairly constant.

Family VERNEUILINIDAE

Genus GAUDRYINA d'Orbigny, 1839

GAUDRYINA CHAPMANI Franke

This species has already been recorded in the Saratoga chalk paper. It occurs also in our samples from the Annona chalk.

GAUDRYINA OXYCONA Reuss

This species is already recorded from the Saratoga chalk, and is found in both the Pecan Gap tongue and the main body of the Annona chalk. It is a widely distributed species, but keeps its characters very well in its wide range.

GAUDRYINA STEPHENSONI Cushman

Gaudryina stephensoni CUSHMAN, *1928*, Contr. Cushman Lab. Foram. Res., vol. 4, p. 108, pl. 16, figs. 6–8; *1931*, Tenn. Geol. Survey, Bull. 41, p. 20, pl. 1, figs. 11*a*, *b*.

Test elongate, tapering, greatest width near the apertural end, the early portion triserial and tricarinate, rapidly increasing in size from the subacute initial end, later and larger portion biserial, with quadrate chambers, the angles distinct, the broader faces of the test flattened or slightly concave, the angles of each chamber marked by fistulose processes which are usually broken through at the tip showing the hollow within; chambers fairly distinct in well preserved specimens; sutures lightly verys depressed; wall finely arenaceous, somewhat rough on the exterior; aperture a low elongate opening on the inner margin of the last-formed chamber. Length, 0.45–0.70 mm.; breadth, 0.20–0.25 mm.; thickness, 0.12–0.15 mm.

This species is a characteristic one of the Taylor marl. It was originally

described from the Wolfe City sand member of the Taylor, in which it is often abundant. It occurs also in the Selma formation of Tennessee, and has a wide distribution in the chalky phases of the Taylor marl. It occurs in both the Pecan Gap tongue and the main body of the Annona chalk.

GAUDRYINA LAEVIGATA Franke
var. PYRAMIDATA Cushman

Gaudryina laevigata FRANKE, var. *pyramidata* CUSHMAN, *1926*, Bull. Am. Assn. Petroleum Geol., vol. 10, p. 587, pl. 16, figs. 8*a*, *b*.

This variety differs from the typical form of the species in being somewhat stouter and the early portion more pyramidal than the type; the periphery instead of being rounded and convex is slightly concave.

This variety was originally described from the Velasco shale of Mexico, but is widely distributed in the Taylor marl of Texas and contemporaneous deposits in adjacent regions. This variety occurs in both the Pecan Gap tongue and the main body of the Annona chalk.

Genus HETEROSTOMELLA Reuss, 1865

HETEROSTOMELLA FOVEOLATA
(Marsson)

This species has already been recorded from the Saratoga chalk, and occurs also in both the Pecan Gap tongue and the main body of the Annona chalk. It is widely distributed in Europe, and is characteristic of the Taylor marl of Texas. There is some variation in the longitudinal rows of irregular openings which characterize the species.

Genus CLAVULINA d'Orbigny, 1826

CLAVULINA AMORPHA Cushman

This species was figured from the Saratoga chalk and also from the Cretaceous of Tennessee. It is widely distributed in America, and occurs both in the Pecan Gap tongue and the main body of the Annona chalk.

CLAVULINA TRILATERA Cushman

This species figured from both the Saratoga chalk and the Selma formation of Tennessee occurs widely distributed in the Upper Cretaceous of Mexico, Trinidad, and the general Coastal Plain of the United States. It occurs in both the Pecan Gap tongue and in the main body of the Annona chalk.

CLAVULINA PLUMMERAE SANDIDGE
Cushman, n.sp.
Plate 50, figures 1*a*, *b*

Clavulina plummerae Sandidge, *1932*, Jour. Pal. vol. 6, p. 270, pl. 41, figs. 17, 18.

Test with the early portion triserial and trilateral, the sides slightly concave or flat, angles subacute; early chambers of the uniserial portion triangular in section, but the later adult chambers becoming rounded and in side view with a definite tapering form both toward the base and toward the apertural end, the greatest breadth being in the middle zone; sutures distinct, becoming more depressed in the adult chambers; wall arenaceous with a considerable amount of cement, smoothly finished; aperture terminal and rounded in the adult, often with a distinct lip. Length up to 1.50 mm. or more; breadth up to 0.50 mm.

The figured specimen does not

show as many uniserial adult chambers as often occur in this species. Frequently several of the peculiarly formed, rounded chambers are present in the adult. The species is well developed in the Taylor marl, and has a wide distribution.

Family VALVULINIDAE

Genus ARENOBULIMINA Cushman, 1927

ARENOBULIMINA PRESLI (Reuss)

This species which has already been recorded from the Saratoga chalk occurs also in both the Pecan Gap tongue and the main body of the Annona chalk.

Family LAGENIDAE

Genus ROBULUS Montfort, 1808

ROBULUS MÜNSTERI (Reuss) (?)
Plate 50, figures 2*a*, *b*

The figured specimen from the type locality of the Annona chalk shows a common form of the Taylor marl which is here referred to Reuss's species. There is a very slight keel, and the central umbo at both sides of the test is of clear shell material, but not as large as in *Robulus macrodiscus* (Reuss). The sutures are nearly tangential in position and very slightly curved.

Genus LENTICULINA Lamarck, 1804

LENTICULINA ROTULATA Lamarck
Plate 50, figures 3*a*, *b*

There are in the Annona chalk specimens similar to that figured here which are very close indeed to the type specimens of this species that I examined in Caen. The umbonate region is decidedly prominent, and the sides very slightly, if at all, convex from the center to the periphery which is not keeled. Lamarck's original types are from the chalk of Meudon in the Paris Basin.

Genus MARGINULINA d'Orbigny, 1826

MARGINULINA INTERMEDIA (Philippi)
Plate 50, figures 4*a*, *b*

Specimens similar to that figured here occur in both the Pecan Gap tongue and the main body of the Annona chalk. The sides are slightly convex, giving an elliptical shape to the chambers in transverse section. The outer periphery is decidedly angled. The later chambers become somewhat uncoiled, and the sutures at the same time become more depressed.

Genus PLANULARIA Defrance, 1824

PLANULARIA TRICARINELLA (Reuss)
Plate 50, figures 5, 6

Cristellaria tricarinella REUSS, *1862* (1863), Sitz. Akad. Wiss. Wien, vol. 46, pt. 1, p. 68, pl. 7, figs. 9*a*, *b*.

Test much compressed, the sides nearly parallel, the outer periphery rounded or somewhat truncate, often with three distinct keels, one median and one at each side; chambers distinct, somewhat uncoiled in the adult, increasing in length as added, height remaining about the same throughout; sutures distinct, raised above the surface, fusing at the periphery into the thickened peripheral margin; wall finely perforate; aperture radiate, at the peripheral angle. Length up to 1.00 mm.; breadth, 0.30–0.50 mm.; thickness, 0.10–0.20 mm.

This species described by Reuss from the Cretaceous of Europe has

not previously been recorded from the Cretaceous of America. The specimens figured here, which are from the Pecan Gap chalk, seem to be very typical. It is a well marked species, and is not the same as the Recent form referred to it by Brady in the *Challenger* report and followed by later authors.

Genus DENTALINA d'Orbigny, 1826

DENTALINA MEGALOPOLITANA Reuss

This species, which has already been recorded from the Saratoga chalk, has also been found in typical form in the Annona chalk. It has a wide distribution both in Europe and America.

DENTALINA ACULEATA d'Orbigny

Plate 50, figure 7

Dentalina aculeata D'ORBIGNY, *1840*, Mém. Soc. géol. France, sér. 1, vol. 4, p. 13, pl. 1, figs. 2, 3.—REUSS, *1845–46*, in Geinitz, Grundr. Verstein., p. 654, pl. 24, fig. 10.

There are in the Annona chalk samples specimens which are usually broken, but which evidently represent chambers and adjacent portions of the connecting necks of this species described by d'Orbigny from the White Chalk of the Paris Basin and also known from other parts of Europe. The chambers are pyriform, and the connecting necks are slender and elongate so that in preparing chalk specimens only the single chambers with portions of the connecting necks are found. Such specimens have been sometimes referred to *Ramulina globulifera*, but our specimens at least seem to be definitely chambers of a *Dentalina*. Complete specimens are to be looked for in the softer portions of the Taylor marl of equivalent age which can be washed with less danger to the foraminiferal content.

Genus SARACENARIA Defrance, 1824

SARACENARIA ITALICA Defrance

Already recorded from the Saratoga chalk this species occurs also in the Annona chalk in our samples.

Genus FRONDICULARIA Defrance, 1824

FRONDICULARIA ARCHIACIANA d'Orbigny

Frondicularia archiaciana D'ORBIGNY, *1840*, Mém. Soc. géol. France, sér. 1, vol. 4, p. 20, pl. 1, figs. 34–36.—CUSHMAN, *1930*, Contr. Cushman Lab. Foram. Res., vol. 6, p. 37, pl. 5, figs. 9–12; *1931*, Tenn. Geol. Survey, Bull. 41, p. 35, pl. 4, figs. 13*a*, *b*.

Test elongate, slightly tapering, greatest width toward the apertural end, much compressed, faces nearly parallel; initial end often with a spine; chambers distinct, of nearly uniform shape, apertural end extended; sutures distinct, raised, sigmoidally curved; wall smooth except for the raised sutures, and the proloculum which often has one or more longitudinal costae; aperture radiate at the end of a slender protuberance. Length up to 1.25 mm.; breadth, 0.20–0.25 mm.; thickness, 0.12–0.15 mm.

This is a very typical form of this part of the Cretaceous, and very widely distributed. It was originally described by d'Orbigny from the White Chalk of the Paris Basin, and occurs widely distributed in the Taylor marl of Texas and contemporaneous deposits in adjacent regions. It occurs in both the Pecan Gap tongue and the main body of the

Annona chalk. It is often accompanied by the following variety.

FRONDICULARIA ARCHIACIANA d'Orbigny, var. STRIGILLATA Bagg
Plate 50, figure 10

Frondicularia archiaciana D'ORBIGNY, var. *strigillata* BAGG, *1898*, Bull. 88, U. S. Geol. Survey, p. 47, pl. 3, fig. 5.—WELLER, *1907*, Geol. Survey New Jersey, Pal., vol. 4, p. 226, pl. 2, fig. 22.

Bagg described this variety from the Cretaceous of New Jersey. It differs from the typical form in having the sutures broken similarly to the enchelon type of faulting, the ends of the separate portions overlapping, the adjacent ones often running some distance up on the chamber itself. The amount of ornamentation thus developed is very variable. The variety occurs with the typical in both the Pecan Gap tongue and the main body of the Annona chalk, and is widely distributed in the Taylor marl.

FRONDICULARIA GOLDFUSSI Reuss
Plate 50, figures 8, 9

Frondicularia goldfussi REUSS, *1860*, Sitz. Akad. Wiss. Wien, vol. 40, p. 192, pl. 4, fig. 7.—CUSHMAN, *1930*, Contr. Cushman Lab. Foram. Res., vol. 6, p. 33, pl. 5, fig. 3.

This species described by Reuss from the Cretaceous of Europe has already been noted in the second reference above from the Taylor marl and Austin chalk of Texas, and the Brownstown marl of Arkansas. The proloculum is usually below the other chambers at the basal line, and there is a generally arrow-shaped form to the test. The proloculum frequently has one or more costae on each side. The wall of the test is smooth, and the sutures are slightly limbate. Specimens are fairly common in the Annona chalk.

Genus FLABELLINA d'Orbigny, 1839

FLABELLINA INTERPUNCTATA von der Marck

This species already recorded from the Saratoga chalk occurs also in the Pecan Gap tongue of the Annona chalk.

Genus KYPHOPYXA Cushman, 1929

KYPHOPYXA CHRISTNERI (Carsey)
Plate 50, figures 11, 12

Frondicularia christneri CARSEY, *1926*, Univ. Texas Bull. 2612, p. 41, pl. 6, fig. 7.

Kyphopyxa christneri CUSHMAN, *1929*, Contr. Cushman Lab. Foram. Res., vol. 5, p. 1, pl. 1, figs. 1–7; *1930*, vol. 6, *Idem*, p. 33, pl. 4, fig. 20; p. 85, pl. 12, fig. 2.—CUSHMAN AND HEDBERG, *1930*, Contr. Cushman Lab. Foram. Res., vol. 6, p. 65, pl. 9, fig. 5.—PLUMMER, *1931*, Univ. Texas, Bull. 3101, p. 168, pl. 12, figs. 9–19.

This is one of the striking species of the Upper Cretaceous of America, occurring particularly in the Taylor formation. It occurs also in Venezuela and in the Cretaceous of deep

EXPLANATION OF PLATE 50

FIGS. 1*a*, *b*—*Clavulina plummerae* Sandidge, ×30. *a*, Side view; *b*, apertural view.
2*a*, *b*—*Robulus miinsteri* (Reuss) (?). ×40. *a*, Side view; *b*, apertural view.
3*a*, *b*—*Lenticulina rotulata* Lamarck. ×40. *a*, Side view; *b*, apertural view.
4*a*, *b*—*Marginulina intermedia* (Philippi). ×40. *a*, Side view; *b*, apertural view.
5, 6*a*, *b*—*Planularia tricarinella* (Reuss). ×50. Fig. 6*a*, Side view; *b*, front view.
7—*Dentalina aculeata* d'Orbigny. ×50.
8, 9—*Frondicularia goldfussi* Reuss. ×30.
10—*Frondicularia archiaciana* d'Orbigny, var. *strigillata* Bagg. ×30.
11, 12—*Kyphopyxa christneri* (Carsey). ×40.
13—*Lagena acuticosta* Reuss. ×120.

Cushman, Cretaceous Foraminifera

wells of Florida. Mrs. Plummer has recently an excellent series showing the microspheric and megalospheric forms of this species. It occurs in both the Pecan Gap tongue and the main body of the Annona chalk at the type localities.

Genus LAGENA Walker and Jacob, 1798

LAGENA ACUTICOSTA Reuss
Plate 50, figure 13

This species which has previously been recorded from the Saratoga chalk occurs in both the Pecan Gap tongue and the main body of the Annona chalk. It has a wide distribution in the Upper Cretaceous.

Family POLYMORPHINIDAE

Genus GLOBULINA d'Orbigny, 1826

GLOBULINA PRISCA Reuss
Plate 51, figure 1

Globulina prisca REUSS, *1862* (1863), Sitz. Akad. Wiss. Wien, vol. 46, pt. 1, p. 79, pl. 9, fig. 8.—CUSHMAN AND OZAWA, *1930*, Proc. U. S. Nat. Mus., vol. 77, Art. 6, p. 76, pl. 12, figs. 6*a–c*.

Test elongate, fusiform, more or less compressed, acuminate toward both ends; chambers elongate, tapering to the base, arranged in an almost triserial series; sutures but little depressed; wall smooth; aperture radiate. Length, 0.50–0.80 mm.; breadth, 0.25–0.35 mm.; thickness, 0.18–0.27 mm.

This is a common Cretaceous species widely distributed. The specimen figured here is a fistulose one with the peculiar radiating tubes from an enlarged chamber which is not unusual in this and other species. It occurs in both the Pecan Gap tongue and in the main body of the Annona chalk.

GLOBULINA LACRIMA Reuss
Plate 51, figure 2

Polymorphina (*Globulina*) *lacrima* REUSS, *1845*, Die Verstein. böhm. Kreide., p. 40, pl. 12, fig. 6; pl. 13, fig. 83.—EGGER, *1899*, Abhandl. kön. bay. Akad. Wiss. München, Cl. II, vol. 21, pt. 1, p. 125, pl. 17, figs. 39, 40.

Globulina lacrima REUSS, *1851*, Haidinger's Nat. Abhandl., vol. 4, p. 27, pl. 4, fig. 9.—CUSHMAN AND OZAWA, *1930*, Proc. U. S. Nat. Mus., vol. 77, Art. 6. p. 77, pl. 19, figs. 1, 2.

Test subglobular, the base broadly rounded, apertural end produced and regularly acuminate, the sides straight and not concave, typically rounded in end view; chambers few, extending back almost to the base; sutures not depressed; wall smooth; aperture radiate, slightly produced. Length, 0.55–0.75 mm.; breadth, 0.40–0.55 mm.; thickness, 0.40–0.55 mm.

This is a common and widely distributed species in the Upper Cretaceous. The figured specimen was largely replaced calcite, and the sutures are practically invisible. It occurs in both the Pecan Gap tongue and the main body of the Annona chalk.

GLOBULINA LACRIMA Reuss
var. HORRIDA Reuss
Plate 51, figure 3

Globulina horrida REUSS, *1845–46* (1846), Verstein. Böhm. Kreide, pt. 2, p. 110, pl. 43, fig. 14.

Globulina lacrima REUSS, var. *horrida* CUSHMAN AND OZAWA, *1930*, Proc. U. S. Nat. Mus., vol. 77, Art. 6, p. 79, pl. 19, fig. 3.

Variety differing from the typical in having the surface finely spinose and usually the apertural end fistulose.

The figured specimen shows this peculiar form that has already been recorded from the clay pit, three miles South of Corsicana, Texas. It

probably has a wide distribution in the Upper Cretaceous of America as it does in Europe. It occurs in both the Pecan Gap tongue and the main body of the Annona chalk.

Family HETEROHELICIDAE

Genus GÜMBELINA Egger, 1899

GÜMBELINA GLOBULOSA (Ehrenberg)

This species, already described and figured in the Tennessee report, occurs in typical form in both the Pecan Gap tongue and the main body of the Annona chalk. It has a world-wide distribution, and varies somewhat in the relative size of the chambers and in the form of the test. A complete study of the species of this genus is necessary before it is possible to be sure of the definite ranges of the different species.

GÜMBELINA STRIATA (Ehrenberg)

This species also occurs in both the Pecan Gap tongue and the main body of the Annona chalk. Striate forms are widely distributed, but the relative amount of the ornamentation as well as its character, whether complete costae or broken ones, is very variable or else there are other species represented in the collections.

GÜMBELINA TESSERA (Ehrenberg)
Plate 51, figures 4, 5

Grammostomum tessera EHRENBERG, *1854*, Mikrogeologie, pl. 32, pt. 2, fig. 18.

Test irregularly rhomboid in front view, much compressed; chambers becoming elongate and rounded in transverse section; sutures distinct, depressed; wall smooth, very finely perforate; aperture an arched opening, at the base of the last-formed chamber in the median line. Length, 0.25–0.35 mm.; breadth, 0.18–0.22 mm.; thickness, 0.08–0.10 mm.

This species was described by Ehrenberg from the Cretaceous of America. It occurs in both the Pecan Gap tongue and in the main body of the Annona chalk, and is widely distributed in the Upper Cretaceous of the southeastern United States. It is a broad, compressed species, the chambers often strongly curved and the sutures decidedly depressed. The specimens figured are not as typical as those that occur in the more easily washed portions of the Taylor marl, and those figured here are for the most part replaced calcite.

Genus BOLIVINOIDES Cushman, 1927

BOLIVINOIDES DECORATA (Jones), var. DELICATULA Cushman
Plate 51, figures 6*a*, *b*

This variety recorded previously from the Saratoga chalk occurs in both the Pecan Gap tongue and the main body of the Annona chalk. While the test is comparatively short and somewhat twisted, the general ornamentation of the surface is more like that of the variety than of the typical species. The short and more typical form with the ornamentation fusing across the sutures also occurs in these chalks

Genus BOLIVINITA Cushman, 1927

BOLIVINITA ELEYI Cushman
Plate 51, figures 7*a*, *b*

Textularia obsoleta ELEY (not Reuss), *1859*, Geol. in the Garden, p. 202, pl. 8, fig. 11C; (?) p. 195, pl. 12, fig. 11.—WRIGHT, *1902*, Irish Nat., p. 179 (list).—(?) CHAPMAN, *1917*, Bull. Geol. Survey, W. Australia, No. 72, p. 16, pl. 12, fig. 116.

Bolivinita eleyi CUSHMAN, *1927*, Contr. Cush-

man Lab. Foram. Res., vol. 2, pt. 4, p. 91, pl. 12, figs. 11*a*, *b*; *1931*, vol. 7, p. 39, pl. 5, figs. 8*a*, *b*.

Test somewhat rhomboid, two or three times as long as broad, greatest width formed by the last two chambers, the periphery flattened as are the other two broader faces, angles very slightly keeled; sutures somewhat indistinct, limbate; surface finely perforate.

This species was originally described from the Cretaceous of England. It occurs commonly in the chalks of the Paris Basin and from England and Ireland. It is very common in the Upper Cretaceous of Texas and in the Taylor marl, especially in the chalky facies. It is also known from the Upper Cretaceous of Arkansas and Antigua. It occurs in the Annona chalk in our material but not from the type locality of the Pecan Gap tongue of the Annona, although it is recorded from the Pecan Gap tongue at other localities.

Genus EOUVIGERINA Cushman, 1926

EOUVIGERINA AMERICANA Cushman

Eouvigerina americana CUSHMAN, *1926*, Contr. Cushman Lab. Foram. Res., vol. 2, pt. 1, p. 4, pl. 1, figs. 1*a–c*; *1931*, Tenn. Geol. Survey, Bull. 41, p. 45, pl. 7, figs. 11*a*, *b*.

Eouvigerina cretacea WHITE (not Heron-Allen and Earland), *1929*, Jour. Pal., vol. 3, p. 42, pl. 4, fig. 18.—MORRISON, *1929*, Bull. Am. Assn. Petroleum Geol., vol. 13, p. 1066 (list).

Test elongate, tapering, greatest breadth toward the apertural end, composed of numerous chambers, the early ones somewhat compressed, coiled, forming one volution or less in the microspheric form, chambers of the adult mostly biserial, but the last-formed ones in fully developed specimens leaving the biserial form and becoming triserial; chambers distinct, polygonal, the upper face flat or slightly convex, the sides concave, making a definitely angled chamber with a sharp periphery on the upper edge, the edges of the chamber with a trace of a keel in the adult; wall ornamented; aperture rhomboid, at the end of a short neck, with a phialine lip. Length, 0.25 mm.; breadth, 0.12 mm.; thickness, 0.08 mm.

This species is found widely distributed in the general Taylor marl of Texas and contemporaneous deposits in adjacent regions. There are numerous variations, some of which undoubtedly have definite ranges and need considerable study. We have specimens from the Pecan Gap tongue and from the main body of the Annona chalk.

Genus PSEUDOUVIGERINA Cushman, 1927

PSEUDOUVIGERINA CRETACEA Cushman

Pseudouvigerina cretacea CUSHMAN, *1931*, Tenn. Geol. Survey, Bull. 41, p. 46, pl. 7, figs. 14*a–c*.

Pseudouvigerina plummerae CUSHMAN, *1931*, Jour. Pal., vol. 5, p. 309, pl. 35, figs. 18*a*, *b* (not Cushman, 1927).

Test elongate, fusiform, greatest breadth above the middle, periphery rounded; chambers inflated, distinct, the earlier ones irregularly biserial, later ones triserial; sutures distinct, depressed; wall smooth but coarsely perforate; aperture terminal, with a short neck and slightly developed lip. Length 0.35 mm.; breadth 0.15 mm.

The specimen previously figured as *Pseudouvigerina plummerae* from the Saratoga chalk belongs to *P. cretacea* recently described from the Selma

formation of Tennessee. *P. plummerae* does occur in the Pecan Gap tongue of the Annona chalk.

Family BULIMINIDAE

Genus BULIMINELLA Cushman, 1911

BULIMINELLA CARSEYAE
Plummer

Bulimina compressa CARSEY, *1926*, (not Bailey, 1851), Univ. Texas, Bull. 2612, p. 29, pl. 4, fig. 14.

Buliminella carseyae PLUMMER, *1931*, Univ. Texas, Bull. 3101, p. 179, pl. 8, fig. 9.

Test ovate, about twice as long as broad, initial extremity bluntly pointed; chambers about four in each mature whorl, turgid, smooth; sutures distinctly depressed, disposed at a strong angle to the elongate axis of the test; aperture small, comma-shaped, in a strong depression on the septal face and overhung by a sharp projection of the apex of the last chamber and marked by a minute and very narrow apertural flap extending down the long side of the septal face. Length, 0.39 mm.; breadth, 0.22 mm.

This species occurs in both the Pecan Gap tongue and the main body of the Annona chalk, and occurs widely distributed in the Taylor marl of Texas and contemporaneous deposits in related regions. It is somewhat similar to *Buliminella colonensis* Cushman and Hedberg described from the Upper Cretaceous of Venezuela, but the latter species is usually shorter and broader.

Genus BULIMINA d'Orbigny, 1826

BULIMINA MURCHISONIANA
d'Orbigny

Previously recorded from the Saratoga chalk, this species occurs also in both the Pecan Gap tongue and the main body of the Annona chalk. It is a widely distributed Upper Cretaceous species originally described by d'Orbigny from the White Chalk of the Paris Basin.

Genus LOXOSTOMUM Ehrenberg, 1854

LOXOSTOMUM CLAVATUM (Cushman)

Plate 51, figures 8*a*, *b*

Bolivina clavatum CUSHMAN, *1927*, Contr. Cushman Lab. Foram. Res., vol. 2, pt. 4, p. 87, pl. 12, figs. 5*a*, *b*.

Test elongate, very tapering, club-shaped, the last-formed portion nearly circular in section, periphery rounded, twenty-three or more chambers in the adult; chambers fairly distinct, somewhat inflated, especially in later growth, the lower margin with backward projecting, short, blunt lobes with depressed areas between; sutures fairly distinct, slightly depressed, earlier ones at right angles to the periphery; wall finely perforate, earlier chambers finely pitted in longitudinal lines; aperture ovate. Length, 0.60 mm.; breadth, 0.20 mm.; thickness, 0.16 mm.

This species was originally described from the Taylor marl from the clay pit of the Dallas Brick Company, one-half mile West of Mesquite, Texas. It has a rather definite range, particularly in the Taylor marl. Our specimens are from the Annona chalk and, being large replaced calcite, do not show the scalloped margin at the base of the chambers in the adult portion as well as do the specimens from the clay samples.

Family ELLIPSOIDINIDAE

Genus PLEUROSTOMELLA Reuss, 1860

PLEUROSTOMELLA SUBNODOSA Reuss

Plate 51, figures 9–11

Pleurostomella subnodosa REUSS, *1860*, Sitz. Akad. Wiss. Wien, vol. 40, p. 204, pl. 8, fig. 2; *1862* (1863), vol. 46, pt. 1, p. 59; *1865*, vol. 52, pt. 1, p. 453.—OLSZEWSKI, *1875*, Sprawozd. Kom. Fizyj. Akad. umiej. Krakowie, vol. 9, p. 111.—MARSSON, *1878*, Mitth. nat. Ver. Neu-Vorpommern u. Rügen, Jahrb. 10, p. 133.—BURROWS, SHERBORN AND BAILEY, *1890*, Jour. Roy. Micr. Soc., p. 555, pl. 8, figs. 27–29.—BEISSEL, *1891*, Abhandl. kön. Preuss. geol. Landes.. vol. 3, p. 64, pl. 12, figs. 30–38.—SCHACKO, *1896*, Arch. Ver. Freunde Nat. Mecklenburg, vol. 50, p. 156 (list).—BAGG, *1898*, U. S. Geol. Survey, Bull. 88, p. 34.—EGGER, *1899*, Abhandl. kön. bay. Akad. Wiss. München, Cl. II, vol. 21, pt. 1, p. 48, pl. 16, figs. 27, 28.—WELLER, *1907*, New Jersey Geol. Survey Pal., vol. 4, p. 202, pl. 1, figs. 32–34.—HERON-ALLEN AND EARLAND, *1910*, Jour. Roy. Micr. Soc., p. 411, pl. 11, fig. 3.—FRANKE, *1912* (1913), Bronn Verh. Nat. Hist. Ver., vol. 59, p. 265; *1925*, Abhandl. geol. pal. Instit. Univ. Greifswald, vol. 6, p. 22, pl. 2, figs. 11*a*, *b*.—CUSHMAN, *1926*, New Zealand Geol. Survey, Pal. Bull. No. 11, p. 41, pl. 9, fig. 10.—CUSHMAN AND HARRIS, *1927*, Contr. Cushman Lab. Foram. Res., vol. 3, p. 131, pl. 25, figs. 23, 26.—FRANKE, *1928*, Abhandl. Preuss. Geol. Landes., vol. 111, p. 129, pl. 11, figs. 28*a*, *b*.—MORRISON, *1929*, Bull. Am. Assn. Petroleum Geol., vol. 13, p. 1066 (list).—STORM, *1929*, Lotus, Prag. vol. 77, p. 60 (list).—WHITE, *1929*, Jour. Pal., vol. 3, p. 53, pl. 5, fig. 15.

Test elongate, tapering from the initial end to the greatest breadth at the last-formed chamber, early chambers completely biserial, later ones becoming irregularly uniserial; chambers distinct, nearly circular in transverse section, somewhat inflated; sutures distinct, slightly depressed, the later ones only slightly oblique; wall smooth, finely perforate; aperture at the side of the chamber, with an overhanging lip and an interior flat tooth.

This species occurs in samples from both the Pecan Gap tongue and the main body of the Annona chalk.

Family ROTALIIDAE

Genus GYROIDINA d'Orbigny, 1826

GYROIDINA UMBILICATA (d'Orbigny)

Rotalina umbilicata d'Orbigny, Mem. Soc. Geol. France, vol. 4, p. 32, pl. 3, figs. 4–6, 1840.

This species has already been recorded from the Saratoga chalk as *Gyroidina glabra* (v. Hagenow). A study of material from the Craie Blanche of the Paris Basin, of material from Rügen, and many other European localities, shows that d'Orbigny's species is very variable, and that many names were later used for it. A synonymy will be given in a later paper.

It occurs in both the Pecan Gap tongue and the main body of the Annona chalk at their type localities.

GYROIDINA DEPRESSA (Alth)

Under this name a small compressed species was described from the Saratoga chalk and elsewhere. A similar form occurs in the Pecan Gap tongue and the main body of the Annona chalk at the type localities.

Topotype material of Alth's species from Lemberg is now available as well as topotype and autotype material of the various species of Reuss and early authors. A study of these in comparison with our American Cretaceous material has been made, and the various names will be taken up in a later paper, and their relationships to our American species discussed in detail.

GYROIDINA MICHELINIANA
(d'Orbigny)

Plate 51, figures 12*a–c*

Rotalina micheliniana D'ORBIGNY, *1840*, Mém. Soc. géol. France, sér. 1, vol. 4, p. 31, pl. 3, figs. 1–3.

Globorotalia micheliniana CUSHMAN, *1931*, Contr. Cushman Lab. Foram. Res., vol. 7, p. 45, pl. 6, figs. 8*a–c*.

This species, originally described by d'Orbigny from the White Chalk of the Paris Basin, has a wide distribution in the Upper Cretaceous. It is a very characteristic species of the Taylor marl often occurring in great numbers. It has also been recorded from the White Chalk of Antigua. The Cretaceous form has a very sharp keel, the dorsal side flattened or very slightly convex, but the ventral side very much extended and deeply umbilicate, and the surface is smooth. I referred this species to *Globorotalia* in the report on the Cretaceous of Antigua. There is some question as to the correct placing of this species, but it is here assigned to *Gyroidina*.

Family CASSIDULINIDAE

Genus PULVINULINELLA Cushman, 1926

PULVINULINELLA ALATA
(Marsson)

This species, recorded previously from the Saratoga chalk, occurs also in the Pecan Gap tongue of the Annona chalk. It is a very widely distributed species as previously noted.

Family CHILOSTOMELLIDAE

Genus PULLENIA Parker and Jones, 1862

PULLENIA QUINQUELOBA Reuss

Already recorded from the Saratoga chalk, this species occurs also in both the Pecan Gap tongue and the main body of the Annona chalk.

PULLENIA QUATERNARIA (Reuss)

This species occurs with the preceding in the Saratoga chalk and also in both the Pecan Gap tongue and the main body of the Annona chalk.

Family GLOBIGERINIDAE

Genus GLOBIGERINA d'Orbigny, 1826

GLOBIGERINA CRETACEA d'Orbigny

Globigerina cretacea D'ORBIGNY, *1840*, Mém. Soc. Géol. France, p. 34, pl. 3, figs. 12–14.—CUSHMAN, *1931*, Tenn. Geol. Survey, Bull. 41, p. 58, pl. 10, figs. 6, 7.

Many things have been referred to this species originally described by d'Orbigny from the White Chalk of the Paris Basin. Typically it has a low spire and five or more chambers in the last-formed whorl, the surface somewhat hispid. The species evidently has a wide range in the Upper Cretaceous, but various things have been assigned to it. It occurs in both the Pecan Gap tongue and the main body of the Annona chalk.

Genus GLOBIGERINELLA Cushman, 1927

GLOBIGERINELLA ASPERA
(Ehrenberg)

Phanerostomum asperum EHRENBERG, *1854*, Mikrogeologie, pl. 30, figs. 26*a, b;* pl. 32, pt. 2, fig. 42.

Globigerina aspera EGGER, *1899*, Abhandl. kön. bay. Akad. Wiss. München, Cl. II, vol. 21, pt. 1, p. 170, pl. 21, figs. 18–20; *1907*, Ber. Nat. Ver. Passau, p. 49, pl. 7, fig. 27.—FRANKE, *1928*, Abhandl. Preuss. Geol. Landes., vol. 111, p. 192, pl. 18, figs. 10*a–c*.

Globigerinella aspera CARMAN, *1929*, Jour. Pal., vol. 3, p. 315, pl. 34, fig. 6.—CUSHMAN, *1931*, Tenn. Geol. Survey, Bull. 41, p. 59, pl. 11, figs. 5*a, b*.

This nearly bilaterally symmetrical species is very widely distributed

and often very common in the Upper Cretaceous of America. The surface is somewhat spinose and roughened, and the chambers are in a single plane, at least in the adult. It occurs in both the Pecan Gap tongue and the main body of the Annona chalk.

Family GLOBOROTALIIDAE

Genus GLOBOTRUNCANA Cushman, 1927

GLOBOTRUNCANA CANALICULATA (Reuss)

Plate 51, figures 14*a–c*

Rosalina canaliculata REUSS, *1854*, Denkschr. Akad. Wiss. Wien, vol. 7, pt. 1, p. 70, pl. 26, fig. 4.

Globigerina canaliculata EGGER, *1899*, Abhandl. kön. bay. Akad. Wiss. München, Cl. II, vol. 21, pt. 1, p. 172, pl. 21, figs. 15–17.

Globotruncana canaliculata CUSHMAN, *1927*, Contr. Cushman Lab. Foram. Res., vol. 3, p. 116, pl. 23, figs. 11*a–c*.—WHITE, *1928*, Jour. Pal., vol. 2, p. 282, pl. 38, fig. 3.

Test small, the dorsal and ventral faces parallel or even slightly concave, periphery broad and squarely truncate or concave; chambers few, usually five in the final whorl, the periphery roughened with short blunt spines, remainder of the surface smooth or slightly spinose in the young; aperture ventral, opening into the umbilical region which is open. Diameter, 0.25–0.30 mm.; thickness, 0.05–0.08 mm.

This species is characteristic of this part of the Taylor marl, and also occurs in both the Pecan Gap tongue and the main body of the Annona chalk. The sides are practically flat and parallel, and the periphery squarely truncate.

GLOBOTRUNCANA ARCA (Cushman)

Plate 51, figures 13*a–c*

Pulvinulina arca CUSHMAN, *1926*, Contr. Cushman Lab. Foram. Res., vol. 2, pt. 1, p. 23, pl. 3, fig. 1.

Globotruncana arca MOREMAN, *1927*, Jour. Pal., vol. 1, p. 100, pl. 16, figs. 16, 17.—CUSHMAN, *1927*, Jour. Pal., vol. 1, p. 169, pl. 28, fig. 15.—CUSHMAN AND CHURCH, *1929*, Proc. Calif. Acad. Sci., vol. 18, p. 518, pl. 41, figs. 1-3.—PLUMMER, *1931*, Univ. Texas, Bull. 3101, p. 195, pl. 13, figs. 7–9, 11.

Globigerina rosetta CARSEY, *1926*, Univ. Texas, Bull. 2612, p. 44, pl. 5, fig. 3.—PLUMMER, *1927*, Univ. Texas, Bull. 2644, pl. 2, fig. 9.

Globotruncana rosetta WHITE, *1928*, Jour. Pal., vol. 2, p. 286, pl. 39, fig. 1.

The reader is referred to a discussion of this species in Mrs. Plummer's recent work, reference to which is given above. There are numerous variations of this species, some of which may be found to have a definite, restricted place in the Cretaceous section. The species occurs in both the Pecan Gap tongue and the main body of the Annona chalk.

Family ANOMALINIDAE

Genus ANOMALINA d'Orbigny, 1826

ANOMALINA COMPLANATA Reuss

Anomalina complanata REUSS, *1851*, Haidinger's Nat. Abhandl., vol. 4, p. 20, pl. 3, fig. 3.—FRANKE, *1928*, Abhandl. Preuss. Geol. Landes., vol. 111, p. 180, pl. 16, figs. 2*a*, *b*.—CUSHMAN, *1931*, Tenn. Geol. Survey, Bull. 41, p. 60, pl. 11, figs. 7*a–c*.

Test planispiral, at least in the adult, much compressed, periphery subacute, earlier coils exposed on both sides at the center; chambers numerous, increasing very slowly in size as added, of nearly uniform shape, the later ones tending to become slightly inflated; sutures distinct, little if at all depressed, slightly limbate; wall smooth but conspicu-

ously perforate, with a slight thickening in the central region at each side; aperture peripheral, extending slightly onto the dorsal side, with a slight lip. Diameter, 0.50 mm.; thickness, 0.15 mm.

This species has recently been figured from the Selma formation of Tennessee. It is widely distributed in the Upper Cretaceous, and occurs in both the Pecan Gap tongue and the main body of the Annona chalk.

ANOMALINA INVOLUTA (Reuss)

Rotalina involuta REUSS, *1851*, Haidinger's Nat. Abhandl., vol. 4, p. 35, pl. 2, fig. 14.

Truncatulina coonensis W. BERRY, *1929*, in Berry and Kelley, Proc. U. S. Nat. Mus., vol. 76, Art. 19, p. 12, pl. 3, figs. 1–3.

Truncatulina ripleyensis W. BERRY, *1929*, l.c., p. 12, pl. 3, figs. 4–6.

Anomalina involuta CUSHMAN, *1931*, Tenn. Geol. Survey, Bull. 41, p. 60, pl. 12, figs. 1–3.

Test trochoid in the young, becoming nearly planispiral and slightly evolute in the adult, periphery rounded in the young, becoming somewhat compressed later; chambers six or seven in the early stages with usually nine in the adult, distinct; sutures very distinct, on the ventral side gently curved and slightly depressed, on the dorsal side with the spiral suture becoming deep and the other sutures meeting it becoming deeply incised so that the ends of the chambers are pinched out at the inner end; wall coarsely perforate; aperture peripheral, extending over onto the dorsal side, with a distinct lip. Diameter, 0.50–0.60 mm.; thickness, 0.15–0.20 mm.

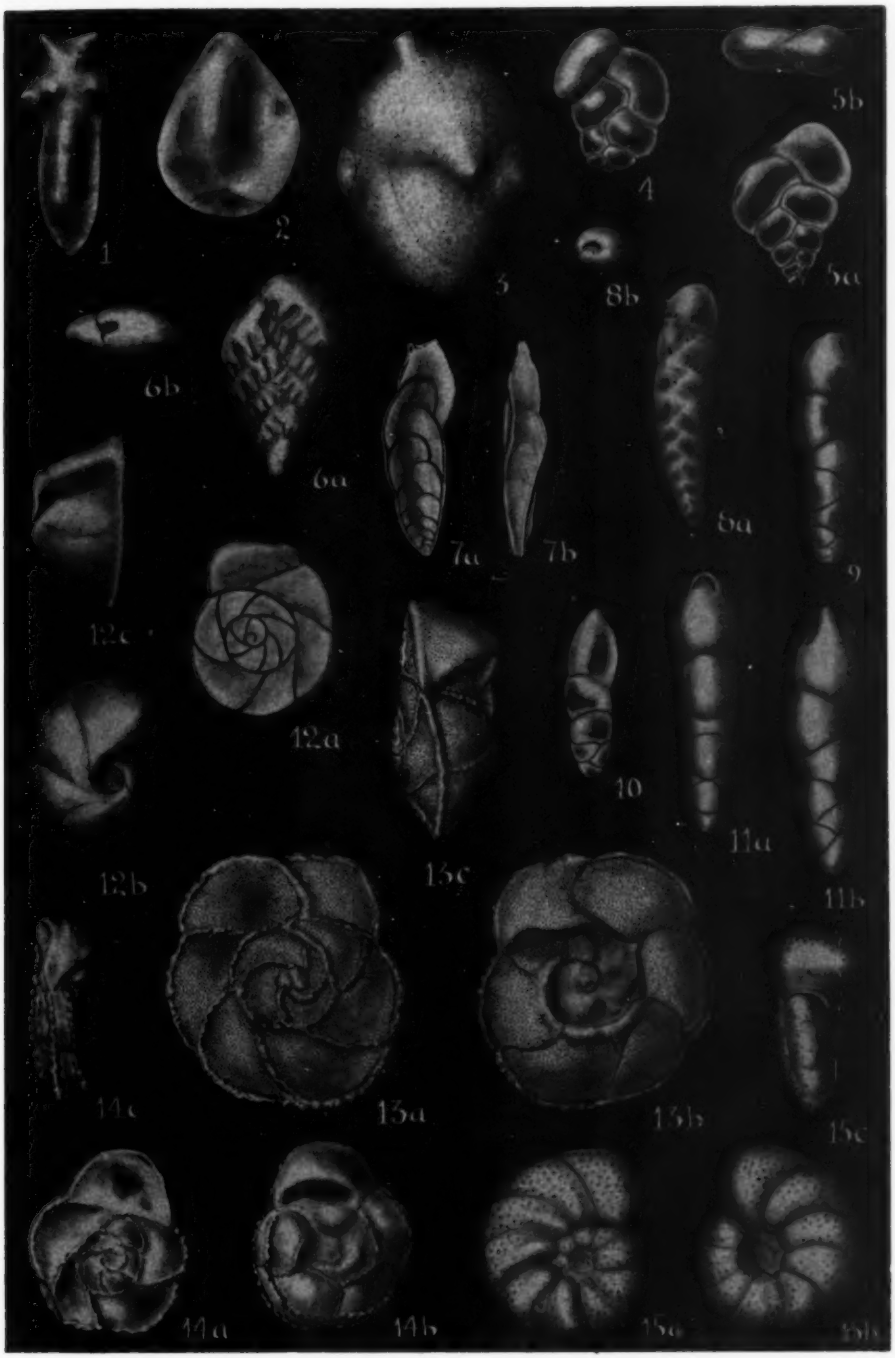
This species is a very variable one as the figures from the Tennessee report will show. As a result of this variable character at different stages in the development of the test, a number of names have been assigned to it. It occurs in both the Pecan Gap tongue and the main body of the Annona chalk. This should not be confused with *Cibicides involuta* (Reuss) in spite of the similarity of names.

ANOMALINA RUBIGINOSA Cushman

Already recorded from the Saratoga chalk, this species occurs in both the Pecan Gap tongue and the main body of the Annona chalk at their type localities. It is a widely distrib-

EXPLANATION OF PLATE 51

FIGS. 1—*Globulina prisca* Reuss. ×40. Fistulose form.
2—*Globulina lacrima* Reuss. ×50.
3—*Globulina lacrima* Reuss, var. *horrida* Reuss. ×40.
4, 5—*Gümbelina tessera* (Ehrenberg). ×75. Fig. 5*a*, Front view; *b*, end view.
6*a*, *b*—*Bolivinoides decorata* (Jones), var. *delicatula* Cushman. ×55. *a*, Front view; *b*, apertural view.
7*a*, *b*—*Bolivinita eleyi* Cushman. ×55. *a*, Front view; *b*, side view.
8*a*, *b*—*Loxostomum clavatum* (Cushman). ×50. *a*, Front view; *b*, apertural view.
9–11—*Pleurostomella subnodosa* Reuss. ×50. Fig. 11*a*, Side view; *b*, front view.
12*a–c*—*Gyroidina micheliniana* (d'Orbigny). ×40. *a*, Dorsal view; *b*, ventral view; *c*, peripheral view.
13*a–c*—*Globotruncana arca* (Cushman). ×50. *a*, Dorsal view; *b*, ventral view; *c*, peripheral view.
14*a–c*—*Globotruncana canaliculata* (Reuss). ×50. *a*, Dorsal view; *b*, ventral view; *c*, peripheral view.
15*a–c*—*Anomalina pertusa* (Marsson). ×60. *a*, Dorsal view; *b*, ventral view; *c*, peripheral view.



Cushman, Cretaceous Foraminifera

uted species as has been previously noted.

ANOMALINA PERTUSA (Marsson)
Plate 51, figures 15*a–c*

Discorbina pertusa MARSSON, *1878*, Mitth. Nat. Ver. Neu-Vorpommern u. Rügen, vol. 10, p. 166, pl. 4, figs. 35*a–e*.

Anomalina pertusa FRANKE, *1925*, Abhandl. geol. pal. Instit. Univ. Greifswald, vol. 6, p. 86, pl. 7, figs. 16*a*, *b*; *1928*, Abhandl. Preuss. Geol. Landes., vol. 111, p. 182, pl. 17, figs. 4*a*, *b*.

Test somewhat evolute on both sides, dorsal side slightly concave, ventral side very strongly so, with the umbilical region widely open, periphery rounded especially in the later portion; chambers distinct, numerous, ten or more in the last-formed whorl; sutures distinct, slightly depressed, strongly curved; wall smooth but coarsely perforate, occasionally some of the chambers on the dorsal side slightly inflated in the middle; aperture peripheral, extending somewhat onto both sides of the test. Diameter, 0.30–0.50 mm.; thickness, 0.15–0.20 mm.

Marsson described this species from the chalk of the Island of Rügen, and it has been recorded by Franke from various localities in the Upper Cretaceous of Germany. It is a characteristic species in the Pecan Gap tongue of the Annona chalk, and may be easily distinguished by the very open umbilical area and the evolute character of the test on both dorsal and ventral sides.

Genus PLANULINA d'Orbigny, 1826

PLANULINA TAYLORENSIS (Carsey)

This species already recorded from the Saratoga chalk becomes larger and more abundant in the lower formations. It occurs in both the Pecan Gap tongue and the main body of the Annona chalk.

Genus CIBICIDES Montfort, 1808

CIBICIDES EXCOLATA (Cushman)

This species, previously recorded from the Saratoga chalk, becomes much more common in the Pecan Gap tongue of the Annona chalk.

CIBICIDES INVOLUTA (Reuss)

This species was previously described from the Saratoga chalk, and occurs also in the Pecan Gap tongue of the Annona chalk.

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A CRUSTACEAN FAUNA FROM THE WOODFORD FORMATION OF OKLAHOMA

C. L. COOPER
Walker Museum, University of Chicago

ABSTRACT

A most unusual fauna, found in concretions in the almost barren Woodford formation, is of interest because it is the first time these forms have been recorded from formations west of the Mississippi River. Nine species, all but two of which are new, are described under two genera.

INTRODUCTION

The fauna described in this paper was first discovered in the summer of 1926 while measuring sections of the Woodford formation on the outcrop along the south edge of the Arbuckle Mountains in northern Carter County, Oklahoma. The formation consists of several hundred feet of alternating beds of brown to black chert and black fissile shale, the individual beds varying from a fraction of an inch to three inches in thickness. The fossils are found in concretions which were found to be numerous in the upper third of the formation. These concretions vary from the size of marbles up to about three inches in diameter. Those containing fossils are of medium size and oval in shape. In one case two and in another three fossils were found in one concretion. About 1 per cent of the concretions contain fossils.

The first specimen was found by Mrs. Cooper, then assisting with the work, who noticed a portion of a *Spathiocaris* protruding from a concretion that had been broken open by weathering. Further search at this locality, on Henryhouse Creek, secs. 4 and 9, T. 2 S., R. 1 E., resulted in the finding of several more specimens. As the work on the formation progressed about 50 specimens of *Spathiocaris* and two of *Colpocaris* were collected during the ensuing four years. One of the latter forms was found and given to the writer by Miss Mildred Armor, a geology student in the University of Oklahoma, and the other by Dr. M. P. White, of Ardmore. Other localities at which *Spathiocaris* collections were made are as follows: West Spring Creek, sec. 24, T. 2 S., R. 1 W.; Hickory Creek, sec. 10, T. 2 S., R. 1. W.; U. S. Highway 77, sec. 12, T. 2 S., R. 1 E.; Cool Creek, sec. 1, T. 3 S., R. 2 E.; Oklahoma Highway 18, sec. 12, T. 3 S., R. 3 E.; and Sycamore Creek, sec. 27, T. 3 S., R. 4 E., all on the south slope of the Arbuckle Mountains and one specimen from Ti Valley, T. 2 N., R. 15 E. Two specimens of *Spathiocaris* were loaned by Dr. George H. Girty from the U. S. Geological Sur-

vey collections, one collected by Dr. E. O. Ulrich from the Woodford near Dougherty, probably in sec. 1, T. 2 S., R. 2 E., and the other by Dr. George D. Morgan from the Stonewall quadrangle.[1]

It was some time after the first forms were collected that a clue to the identity of the Spathiocarids was obtained, as paleontologists working west of the Mississippi River were not acquainted with forms even remotely similar to them. Dr. E. O. Ulrich, to whom the collections were shown, remembered collecting similar forms in Kentucky. Some months later, on a visit to Dr. Ulrich's laboratory, the undescribed Kentucky forms were seen to be similar to the Oklahoma specimens. Dr. Ulrich also gave the writer a reference to a paper by Dr. Rudolf Ruedemann in the *Bulletin of the New York State Museum*, and this lead formed the basis for the descriptions in this paper. The collection was sent to Dr. Ruedemann, who substantiated the classification of the forms as Spathiocarids, and who also gave much help with the description of the Colpocarids.

[1] Morgan, George D., Geology of the Stonewall Quadrangle, Oklahoma: Bu. Geology, Bull. 2, pl. 52, fig. 4.

DESCRIPTION OF SPECIES

Order CRUSTACEA

Family CERATIOCARIDAE McCoy, 1849

Genus COLPOCARIS Meek, 1872

Colpocaris MEEK, 1872, Proc. Acad. Nat. Sci. Philadelphia, p. 323.

COLPOCARIS ELYTROIDES Meek

Ceratiocaris (*Colpocaris*) *elytroides* MEEK, 1872, Proc. Acad. Nat. Sci. Philadelphia, p. 334, pl. 24.

Ceratiocaris (*Colpocaris*) *elytroides* MEEK, 1875, Geol. Survey of Ohio, vol. 2, pt. 2, pp. 319, 320, pl. 18, figs. 5*a*, *b*, *c*. (Base Waverly group at Danville, Ky.)

Plate 52, figures 1–4

The carapace is narrow, slightly elliptical in form, and distinctly convex with the dorsal margin gently arcuate from end to end. The dorsal margin is terminated in a narrow projection at the anterior end as a result of a curved truncation, or cleft, having much the appearance of a gill slit. Very faint serrated ridges parallel the dorsal margin almost throughout the entire length of the shell, but curve gently inward toward the posterior end where they join the dorsal ridge in a point. Minutely crenate carinae border, but do not parallel the lower margin, being farthest away from the middle where the crest of the carina is perforated by a single row of minute rounded pores. The surface of the carapace is ornamented by very faint striae in addition to the two sets of carinae. These striae branch from the dorsal ridge toward the posterior end, where they turn so as to parallel the anterior margin, but meet the posterior half of the lower margin at a low angle. The striae on the lower side of the lower carinae curve abruptly away to the edge of the shell, in a direction opposite to that of the striae on the upper side.

Ruedemann[2] has kindly contributed the following description of the markings on the shell made by the attachment of the heart ligaments and the hepatic lobe or digestive glands which he first observed several years ago in some specimens from Tennessee.

The specimen of *Colpocaris elytroides* is of special interest as it retains impressions of the interior surface of the carapace that give an indication of the location of certain organs not often seen in these primative forms. Like impressions have already been observed by the writer years ago in examples of the same species from Tennessee but not yet described, and this occasion may therefore serve the purpose of directing attention to them.

The first of these markings are the "serrate ridges" found on each valve below the hinge-line, and seen also on the interior surface. They are low, straight, about 3 mm. below the dorsal hinge-line that bear about 20 transverse slit-like depressions, more crowded and longer in front and farther apart and shrinking to little pits in the posterior portion. From their position and character, there can be no doubt that these ridges and pits are connected with the heart, the pits marking the little nodes of the interior which were the attachment places of the ligaments holding the long, tubular heart in place. Their closer arrangement in the anterior portion is probably connected with the fact that the strongest action of the heart takes place in front where the cephalic artery is given off.

The second marking is only observable where the exoskeleton is broken out, or rather it becomes noticeable by the fact that the shell, probably very thin at this spot, is exfoliated, leaving a light colored kidney-shaped impression, about 5 mm. wide and situated just behind the deep frontal sinus. Its position is oblique to the dorsal side with the convex part forward. From the interior base rises a central trunk-like vein, from which a multitude of fine, anastomosing and radiating veinlets branch. The location and character of these interior impressions indicate their close connection with the digestive system beginning at the mouth. They correspond to the markings left by the hepatic lobe or digestive glands seen in the interior of recent crustacean carapaces and also often on the inside of the free cheeks of the cephalon of trilobites.

[2] Ruedemann, Rudolf, personal communication.

Length of shell (restored), 30 mm.; width, 11 mm.; thickness, 6½ mm.; striae, 20 to 25 per mm.

Woodford formation, sec. 30, T. 2 S., R. 2. E., along east side of U. S. Highway 77, Arbuckle Mountains, Oklahoma. Specimen collected by Miss Mildred Armor, student at the University of Oklahoma.

In this discussion the orientation of this form follows that of Ruedemann[3] and Zittel[4] who designate the pointed, downcurved termination of the dorsal margin as the anterior end. Meek,[5] who first described *Colpocaris*, describes this projection as the posterior end. The later writers have had the benefit of more data on the anatomical structure of this form, and therefore were better able to differentiate the anterior and posterior ends, while Meek's descriptions were made from the external characteristics of the carapace alone.

COLPOCARIS WOODFORDI
Cooper, n.sp.
Plate 52, figures 5–7

The carapace is large, the valves subelliptical and about three times

[3] Ruedemann, Rudolf, personal communication.

[4] Zittel, Karl A., *Textbook of Paleontology:* vol. I, p. 751, 1927.

[5] Meek, F.B., The invertebrate fossils of the Waverly group and Coal Measures of Ohio: *Geol. Survey of Ohio*, vol. 2, pt. 2, pp. 317–320, pl. 18, figs. 5 a–c, 6 a–c, 1875.

as long as high. The dorsal and ventral margins are equally arcuate and the posterior and anterior ends are approximately equal in width. The dorsal margin is terminated in a downward projecting point which overhangs the end of the ventral margin about 5 mm. The end of the ventral margin is rounded and gently incurved, giving the anterior end an almost circular appearance. The sinus is open and directed sharply upward even more than in *C. elytroides*. The ridge formed by the heart ligaments is poorly developed, but the transverse depressions are present, averaging 3.5 mm. apart and in a line 7 mm. below the dorsal ridge and almost parallel to it. The dorsal view shows that the sides are parallel in the anterior half of the carapace, then tapering gradually to the posterior end. The surface of the shell is covered with small pits. The area immediately behind the anterior sinus and midway between the dorsal and ventral margins carries many slightly raised tubercular spots which average 0.5 mm. in diameter. The area of attachment of the digestive muscles are irregularly elongate in shape, narrow at the top, becoming narrower about the middle where it is slightly curved, then wide toward the bottom. It is located 8 mm. back from the anterior sinus.

Length, restored, about 70 mm.; width, 26 mm.; greatest thickness, 20 mm.

Woodford formation, sec. 30, T. 2 S., R. 2 E., along east side of U. S. Highway 77, Arbuckle Mountains, Oklahoma. Specimen collected by Dr. M. P. White.

Family DISCINOCARIDAE Woodward

Discinocaris WOODWARD, 1856, Quar. Jour. Geol. Soc. London, vol. 22, pp. 503–505. (Moffat shales).

SPATHIOCARIS GOULDI Cooper, n. sp.

Plate 52, figures 8–10, 22

The specimens referred to this species, though fragmentary, are very much different from other described species. The restored shell has an elongate appearance with a distinct anterior notch or cleft, having much the same shape as *S. emersoni*, figured by Ruedemann,[6] though only two-thirds as large. The surface is covered with concentric folds or lines that are much coarser than in other species of *Spathiocaris* (six in 5 mm. at the posterior edge and slightly smaller near the apex). The folds are deep-set, with rounded ridges and troughs which are, for the most part, of equal width. In one specimen these ridges are somewhat asymmetric toward the cleft, the side nearer the apex being the steeper. Beginning at the apex and extending around it concentrically is a smooth area or band covered with very faint lines which are most distinct in the medial area, fusing or growing together on either side.

Length, restored, about 40 mm.; width, 32 mm.

[6] Ruedemann, Rudolf, Paleontologic contributions from the New York State Museum: *New York State Museum Bull. 189*, p. 96, pl. 31, fig. 7, 1916.

Upper Woodford formation, sec. 30, T. 2 S., R. 2 E., along U. S. Highway 77, Arbuckle Mountains, Oklahoma.

SPATHIOCARIS TENUICOSTA
Cooper, n. sp.
Plate 52, figures 11, 12

The shell is folded along the median line with the anterior margin largely missing. The growth lines are concentric about the apex, very fine and slightly smaller near the anterior end (14 in 5 mm. near the apex and 10 in 5 mm. near the posterior end). A low, abrupt median ridge begins about 6 mm. back of the apex and runs to the posterior margin; 6 mm. from its beginning it flares and at the edge of the specimen is 2 mm. broad. Anteriorally this ridge disappears into an abrupt trough about 1.5 mm. wide and 0.5 to 0.75 mm. deep. Very faint lines parallel the median ridge and trough, one on each side, from the anterior to the posterior end.

Measurements cannot be accurately obtained as the shell is very fragmentary, Length, about 28 mm.; width, about 16 mm.

Upper Woodford formation, sec. 36, T. 2 S., R. 2 E., Arbuckle Mountains, Oklahoma.

SPATHIOCARIS PLICIFERA
Cooper, n. sp.
Plate 52, figures 13, 14

The shell is folded along the median line bringing the two anterior wings together, forming a keel-like edge to the specimen. The central part of the dorsum is folded into a number of elongate plications, 2 to 4 mm. in diameter, several of which are hollow, and are apparently tubes leading inside the shell. A second row of plications, about 10 mm. in front of those on the dorsal margin, apparently were utilized earlier in the life

EXPLANATION OF PLATE 52

FIGS. 1, 2, 3, 4—*Colpocaris elytroides* Meek. 1, Anterior view, ×1. 2, Right side, ×1. 3, Sketch of digestive muscle attachment, ×6. 4, Dorsal view, ×1.

5, 6, 7—*Colpocaris woodfordi* Cooper, n. sp. 5, Anterior view, ×½. 6, Right side, ×½. 7, Sketch of digestive muscle attachment, ×7.

8, 9, 10, 22—*Spathiocaris gouldi* Cooper, n. sp. 8, Left side, Sycamore Creek. 9, Left side, U. S. Highway 77. 10, Median area of fig. 8. 22, An irregularly folded specimen showing folds.

11, 12—*Spathiocaris tenuicosta* Cooper, n. sp. Sec. 36, T. 2 S., R. 3 E. 11, Left side. 12, Median area.

13, 14—*Spathiocaris plicifera* Cooper, n. sp. Sec. 30, T. 2 S., R. 3 E. 13, Left side. 14, Median area.

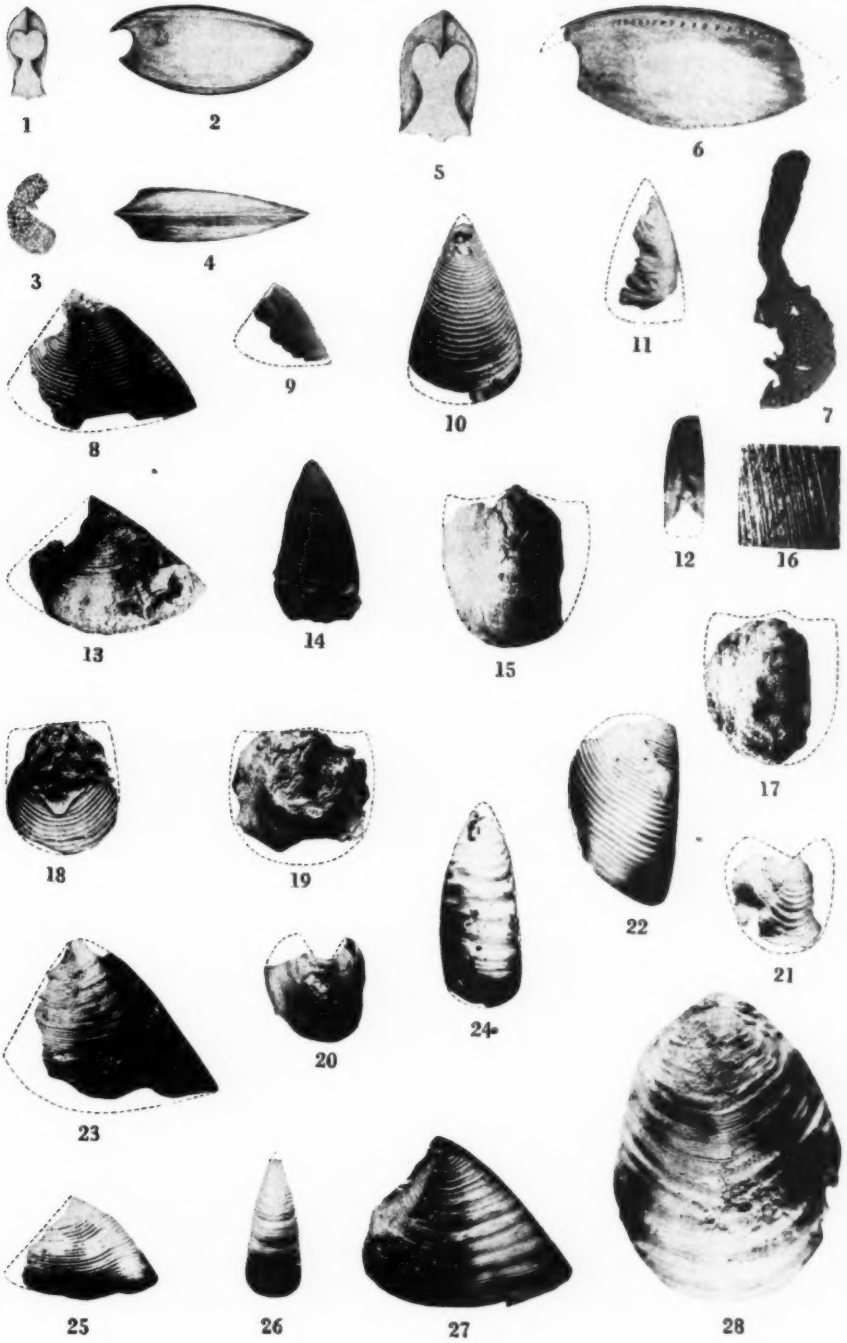
15, 16, 17—*Spathiocaris striatula*, Cooper, n. sp. 15, Entire valve, with right side folded down. Sycamore Creek. 16, Striations of fig. 15, ×10. 17, Entire valve, with side and corner folded, Sec. 36, T. 5 S., R. 1 E.

18, 19, 20, 21—*Spathiocaris williamsi* Ruedemann. 18, Fragment restored. Ti Valley. 19, Same as fig. 18. Sec. 36, T. 2 S., R. 2 E. 20, Carapace partly restored. Same locality as fig. 19. 21, Another fragment restored. Sec. 12, T. 3 S., R. 3 E.

23, 24, 25, 26, 27—*Spathiocaris woodfordi* Cooper, n. sp. 23, Left side of shell. Sec. 36, T. 2 S., R. 2 E. 24, Median area of fig. 23. 25, Left side. Stonewall quadrangle. 26, Median area of fig. 25. 27, Mould of the right side of a shell. Sec. 30, T. 2 S., R. 1 E.

28—*Spathiocaris ulrichi* Cooper, n. sp. Entire valve.

Note: All figures ×2/3 except where noted above.



Cooper, Early Mississippian Crustacea

of the animal, as they are now closed by the continued growth of the shell. The surface of the shell is sculptured similar to *S. woodfordi*, except that the transverse striae are absent.

Length, 32–35 mm.; width, about 60 mm. if shell were flat, or about 40 mm. if arched along the median line.

Upper Woodford formation, sec. 30, T. 2 S., R. 1 E., Arbuckle Mountains, Oklahoma.

SPATHIOCARIS STRIATULA
Cooper, n. sp.
Plate 52, figures 15–17

The shell is ovate or semi-elliptical in outline, the greatest width about one-third the distance back from the apex. The anterior edge is convex (about 120°) in contrast to other forms which have a cleft or notch anteriorally. The shell is arched laterally and transversely and the posterior margin is slightly recurved or turned up. The shell is free from plications or strong folds and is entirely smooth except for very fine (about 20 in 5 mm.) growth lines arranged concentrically around the apex. These growth lines are very uniform in size and run parallel to the lateral and posterior margins, curving gradually to meet the anterior margin at almost right angles. All specimens show very fine, though distinct, striations radiating from the apex to the lateral and posterior margins of the shell.

Length, 32 mm.; width, 34 mm.; height, about 8 mm.

Upper Woodford formation. Type from Sycamore Creek, sec. 34, T. 3 S., R. 4 E.

SPATHIOCARIS WILLIAMSI
Ruedemann
Plate 52, figures 18–21

Spathiocaris williamsi RUEDEMANN, 1916, New York State Mus. Bull. 189, p. 96, pl. 31, figs. 1, 2. Carboniferous (Waverlyan) Cleveland shale, Mill Creek, Newberg, near Cleveland, Ohio.

The apex is near the anterior margin, on the median line. The growth lines are concentric and curve sharply inward, indicating a wide, open cleft on the anterior end. The growth lines are coarse, about 1 mm. broad at the posterior end and finer (0.5 mm.) near apex.

Length, about 25 mm.; width, restored, 22–27 mm.

Upper Woodford formation, Arbuckle Mountains, Oklahoma.

SPATHIOCARIS WOODFORDI
Cooper, n. sp.
Plate 52, figures 23–27

The shell is strongly folded along the median line so that the cleft is closed, forming a keel-like ridge. The markings are similar to *S. emersoni* but the width of the shell is much greater than the Devonian form. The outline is semi-elliptic. The sculpture consists of low, broad, irregular folds on which are superimposed fine concentric growth lines which become wider towards the posterior end (15 in 5 mm. to 10 in 5 mm.). These lines are also somewhat larger in the middle than near the anterior edge. Fine striae are to be found on the exfoliated portions of the shell radiating from the apex to the lateral and posterior margins.

Width of restored shell, 70 mm.; length, about 45 mm.

Upper Woodford formation, Arbuckle Mountains, Oklahoma.

SPATHIOCARIS ULRICHI
Cooper, n. sp.
Plate 52, figure 28

The shell is semi-elliptical in outline, much narrower at the apex and broadly curved transversely and longitudinally, placing the greatest height along the median line just back of the apex. The shell is sculptured transversely by several broad undulations, upon which are superimposed fine lines concentrically around the apex. Fine striae also radiate in straight lines from the apex to the posterior margin.

Width, 44 mm.; length, 60 mm.; height, about 20 mm.

Woodford formation, near Dougherty, Arbuckle Mountains, Oklahoma. Type specimen collected by Dr. E. O. Ulrich, and loaned to the writer by Dr. George H. Girty.

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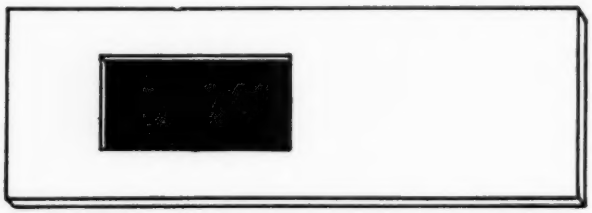

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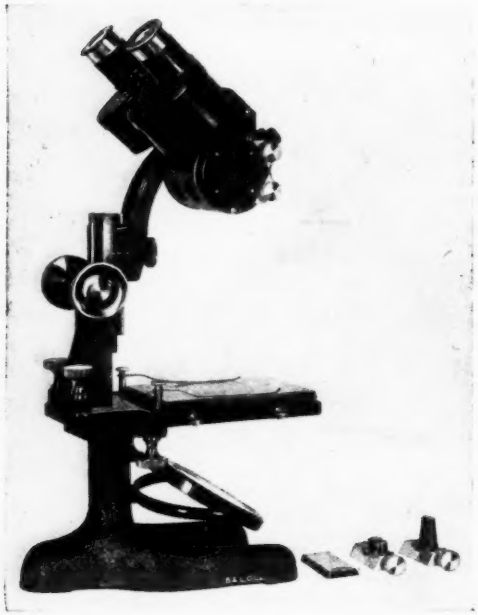

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